ASSESSMENT OF QUANTITATIVE AND QUALITATIVE RESPONSE OF HYBRID MAIZE (*ZEA MAYS* L.) UNDER DIFFERENT AGRO-CHEMICALS AND TEMPORAL DYNAMICS

Thesis Submitted for the Award of the Degree of

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in

Agronomy

By

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DECLARATION

I, hereby declared that the presented work in the thesis entitled "**Assessment of Quantitative and Qualitative Response of Hybrid Maize (*Zea mays* L.) under different Agro-chemicals and Temporal Dynamics**" in fulfilment of degree of **Doctor of Philosophy (Ph.D.)** is outcome of research work carried out by me under the supervision of **Dr. Prasann Kumar** working as Assistant Professor in the Department of Agronomy School of Agriculture of Lovely Professional University, Punjab, India. In keeping with general practice of reporting scientific observations, due acknowledgements have been made whenever work described here has been based on findings of another investigator. This work has not been submitted in part or full to any other University or Institute for the award of any degree.

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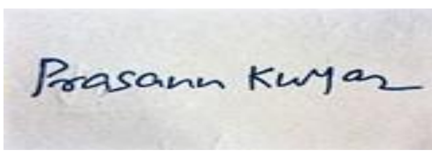
CERTIFICATE

This is to certify that the work reported in the Ph.D. thesis entitled "**Assessment of Quantitative and Qualitative Response of Hybrid Maize (*Zea mays* L.) under different Agro-chemicals and Temporal Dynamics**" submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Department of Agronomy School of Agriculture is a research work carried out by **Priyanka Devi (12009879)** is bonafide record of his/her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.



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Abstract

Significant challenges to agricultural yield come from climate change and variation. The world's crop production will suffer as a result of climate change. If climate change trends continue, worldwide average maize (corn) crop yields might drop by 24 per cent by the end of the century. It is projected that temperatures will rise, rainfall patterns will change, and surface concentrations of carbon dioxide will increase due to human emissions of greenhouse gases; all of these factors make it more challenging to grow maize. Changing planting dates and using various agrochemicals is a more efficient adaptation strategy than management. Globally, crop models are employed as part of a decision support system for optimum crop management in light of varying climate conditions. The variance in crop yield can be attributed primarily to the sowing date, which is influenced by the significant fluctuations in weather conditions during different seasons and within varying climatic zones. To avoid yield loss and protect the ecosystem through effective sowing of maize in the field, to determine the optimal sowing dates for maximum yield without compromising the crop's productivity or the surrounding ecosystem. This experiment aimed to assess the impact of various planting dates along with the effects of foliar application of salicylic acid (SA) and sodium nitroprusside (SNP) on the morphological traits of maize was investigated. Nitric oxide (NO) is a free radical, while salicylic acid (SA) is a phenolic phytohormone. They are both essential signal molecules with important biochemical and physiological roles. The main dangers to agricultural systems and crop output come from abiotic stressors, particularly during the first stages of plant growth. It has been found that the molecules NO and SA effectively reduce the harmful effects of abiotic stress in plants. SA is doing a wide variety of activities in challenging conditions. A field experiment was conducted at the School of Agriculture, Lovely Professional University, Punjab, India, in an open-air environment in the *spring* of 2022 with one variety of maize crop – PMH-10, taken from the PAU, Punjab. The experiment was laid out under the split-plot design having two factors, i.e., sowing dates and agrochemicals. A suitable sprayer was utilized to perform an exogenous foliar application of Salicylic acid and Sodium nitroprusside. The recommended package of practice for maize crops in Punjab was carried out throughout the experiment. This experiment showed that applied agrochemicals showed positive results in spring maize when grown under different sowing dates. Among the used agrochemicals, SA (A2) and SNP (A3) were able to improve the morphological parameters of maize like plant height (cm), number of leaves, Stem diameter (mm), internodal length (cm), leaf area (cm^2), leaf area index (LAI), along with the growth parameters includes CGR, RGR and NAR in different sowing dates. The application of Salicylic acid and sodium nitroprusside increased the required pigments for the development of plants, which directly affect the yield and quality of maize. The application of agrochemicals in early and late sowing showed numerous plant physiological activities, including the response to adverse environmental conditions, and imparts plant defence inducing systemic acquired resistance. The application of SA decreased the content of lipid peroxidation and membrane injury index (MII). Applied agrochemicals also increased the total soluble sugar, total soluble protein, total starch, total amylopectin, total reducing and non0reducing sugar and amylose in maize leaves as well as in seeds which directly improved the quantity and quality of maize under different sowing dates. The yield attributes like number of cobs, cob length (cm) number of kernels/cobs, the number of kernels rows/cob, the weight of cobs g, the weight of kernels g, stover yield, grain yield and test weight of maize were increased in that treatments where salicylic acid was applied as compared to other agrochemicals under different sowing dates. The quality parameters like crude fibre, total soluble sugar, total soluble protein, nitrogen uptake, phosphorus uptake, and potassium uptake from leaf and seeds also improved in applied agrochemicals compared to control in early and late sowing compared to the optimum sowing. Among different sowing dates, the late-sown maize showed a better result than the early sowing in morpho-physiological yield and quality parameters of maize. The interaction effects of sowing dates and applied agrochemicals in morphological, biochemical, yield attributes, quality and economics analysis of maize parameters were significant.

Keywords: Abiotic stress, Agrochemicals, Climate change, Maize, Salicylic acid, Sodium nitroprusside, Zero hunger, No poverty

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Place: LPU, Phagwara ***Priyanka Devi***

Date:

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LIST OF ABBREVIATIONS	SYMBOLS USED
;	Semicolon
%	Percent
:	Colon
^{0} C	Degree Celsius
Chl a	Chlorophyll a
Chl b	Chlorophyll b
cm^2	Square centimeter
CAT	Catalase
cm	Centimeter
DAS	Days after sowing
DDW	Double distilled water
EC	Electrical conductivity
et al.,	Co-worker
FW	Fresh weight
G	Gram
H_2SO_4	Sulphuric acid
Kg/ha	Kilogram per hectare
M	Molar
MDA	Malondialdehyde
mg	milligram
ml	Milliliter
mM	millimolar
NO	Nitrous oxide
ppm	Parts per million
R	Replication
rpm	Rotation per minute
UV	Ultra violet
w/v	Weight by volume
MSI	Membrane stability index
MII	Membrane injury index

v/v	Volume by volume
SA	Salicylic acid
SNP	Sodium nitroprusside
DW	Dry weight
LSD	Least significant difference
Max.	Maximum
CV	Coefficient of Variance
dsm^{-1}	Deci Siemens per meter
>	Greater than
<	Less than
pH	Soil reaction
OC	Organic matter
N	North
S	South
W	West
E	East
K	Potassium
P	Phosphorous
N	Nitrogen
CGR	Crop growth rate
RGR	Relative growth rate
NAR	Net assimilation rate
SPAD	Soil plant analysis development
LA	Leaf Area
LAI	Leaf Area Index
DMRT	Duncan's multiple range test
CI	Chlorophyll Index

CHAPTER-I

Introduction

The global environment is undergoing unprecedented changes due to climate change, leading to profound consequences for agriculture, particularly the cultivation of essential staple crops like maize (*Zea mays* L.). Maize, also known as corn, is vital in global food security, serving as a primary source of calories, livestock feed, and raw materials for various industries(Bhupenchandra et al., 2022; Ma et al., 2022; Bibi and Rahman 2023; Zangani et al., 2023; Mahdieh et al., 2022; Junming Liu et al., 2023; Wen et al., 2023; Nandi et al., 2023; He et al., 2023; Zhaoxin Li et al., 2023). However, climate change's continued and escalating impacts threaten maize production worldwide. Climate change, broadly defined as the long-term alteration of Earth's climate patterns, has manifested in various ways, including rising temperatures, shifting precipitation patterns, and increasing extreme weather events. These changes have far-reaching implications for agriculture, disrupting growing seasons, increasing the risk of droughts, and exacerbating crop heat stress. Among these effects, the impacts on maize production are particularly significant, given its importance in global agriculture (Malik et al., 2020). This research embarks on a comprehensive exploration of the multifaceted challenges posed by climate change to maize production. Specifically, this study delves into the influence of elevated temperatures and erratic rainfall on maize growth and productivity, focusing on spring maize. Additionally, it investigates the crucial role of sowing dates and the potential benefits of applying salicylic acid and sodium nitroprusside as growth regulators to mitigate the environmental stressors associated with climate change (Su et al., 2023; Yuhui Liu et al., 2023; Changji Song et al., 2023; Moghaddam et al., 2023; Coelho et al., 2023; Wu et al., 2023).

The objectives of this research are twofold. First, it seeks to provide an in-depth understanding of how climate change, characterized by increased temperatures and changing precipitation patterns, affects the various stages of maize development, ultimately influencing maize yield and quality. Second, it intends to assess the efficacy of changing sowing dates as well as the use of salicylic acid as well as sodium nitroprusside in mitigating the negative effects of different environmental stress on maize harvests. The significance of this research cannot be overstated. As the global population grows, food security becomes ever more critical. Maize, as a staple crop, this endeavour. By comprehensively assessing the impact of climate change on maize production and exploring potential mitigation strategies, this study contributes to our understanding of how agriculture can adapt to a changing world. It is hoped that the findings will guide policymakers, agronomists, and farmers in making informed decisions to secure maize production and, by extension, global food security in the face of climate change. Climate change refers to long-term alterations in Earth's average weather patterns, particularly in temperature, precipitation, and other climatic factors. These changes are typically observed over decades to millions of years and can significantly impact the environment, ecosystems, and human societies (Chanu et al., 2023; Marak et al., 2023; YU et al., 2023; Sabourifard et al., 2023; Jahangirlou et al., 2023; Kühling et al., 2023). Climate change is primarily driven by human activities, with the release of greenhouse gases (such as carbon dioxide, methane, and nitrous oxide) into the atmosphere being a major contributing factor (Singh et al., 2018). These gases trap heat from the sun and cause a gradual warming of the planet, a phenomenon often referred to as global warming. This leads to a series of interconnected and complex consequences:

1. **Rising Temperatures:** Global temperatures increase, leading to more frequent and severe heatwaves. This can have detrimental effects on ecosystems, agriculture, and human health.

2. **Melting Polar Ice and Glaciers:** Higher temperatures cause melting polar ice caps as well as glaciers, which contributes to increasing sea levels. This can result in coastal flooding and community displacement.

3. **Changing Precipitation Patterns:** Climate change can alter rainfall patterns, leading to increased droughts in some regions and more intense rainfall and flooding in others. These changes can disrupt agricultural practices and water availability.

4. **Extreme Weather Events:** Climate change is associated with increased frequency and intensity of extreme weather events, such as hurricanes, cyclones, and wildfires.

5. **Ocean Acidification:** The world's seas are becoming increasingly acidic as a result of their absorption of surplus carbon dioxide. Endeavor. This harms marine life, particularly creatures with calcium carbonate shells or skeletons.

6. **Loss of Biodiversity:** Changing climate conditions can lead to habitat loss and affect plant and animal species' distribution, potentially resulting in certain species' extinction.

7. **Impacts on Agriculture:** Altered climate conditions can affect crop yields and the availability of arable land, potentially leading to food shortages and price volatility.

8. **Public Health Concerns:** Changes in temperature and precipitation can impact the spread of diseases, such as vector-borne illnesses like malaria and dengue fever.

While natural climatic fluctuation has happened throughout Earth's history, the present rate of climate change is mostly linked to human actions, most notably the use of fossil fuels, deforestation, and industrial processes. Climate change mitigation efforts include lowering greenhouse gas emissions, shifting to renewable energy sources, and implementing sustainable land-use practises. Adaptation strategies are also crucial to address the changes that are already occurring and those that are expected to continue (Fadiji et al., 2022). Climate change has a profound impact on agriculture production and productivity, posing significant challenges to food security and the livelihoods of millions worldwide (Bibi et al., 2023; Bhupenchandra et al., 2022). The effects of climate change on agriculture are multifaceted and can vary by region, but they generally include the following:

1. **Altered temperature patterns:**

    - **Warmer temperatures:** Rising temperatures can have both positive along with negative effects. In some regions, warmer temperatures can extend growing seasons, potentially allowing for multiple crop cycles. However, excessive heat during critical growth stages can reduce yields and damage crops (Dias et al., 2022).

2. **Shifted Precipitation Patterns:**

- **Droughts:** Changes in precipitation patterns can lead to more frequent and severe droughts, which can reduce crop yields, degrade soil quality, and increase water stress for agriculture.
- **Floods:** Conversely, some regions experience more intense rainfall and flooding, which can damage crops, cause soil erosion, and disrupt planting and harvesting.

3. **Altered Pest and Disease Dynamics:**

- **Pests and Diseases:** Climate change can affect the distribution and behaviour of pests and diseases. Warmer temperatures and altered humidity levels can create more favourable conditions for certain pests and diseases, requiring increased pest control measures and potentially leading to crop losses (Singh et al., 2023).

4. **Changing Growing Seasons:**

- **Unpredictable Timing:** Irregular temperature and precipitation patterns can disrupt the predictability of planting and harvesting times, making it more challenging for farmers to plan and manage their crops effectively.

5. **Water Resource Challenges:**

- **Reduced Water Availability:** Climate change can affect water resources, reducing water availability for irrigation, livestock, and general agricultural needs, especially in regions dependent on glacial meltwater or rainfall.

6. **Impacts on Crop Yields and Quality:**

- **Reduced Yields:** Climate change can reduce crop yields, affecting staple crops like rice, wheat, and maize. This can result in food shortages and increased prices.
- **Reduced Nutrient Content:** Elevated carbon dioxide levels may lead to reduced nutrient content in some crops, making them less nutritious (Backer et al., 2018).

7. **Impact on Livestock Farming:**

   - **Heat Stress:** Higher temperatures can stress livestock, reducing their productivity and sometimes leading to livestock losses.
   - **Altered Grazing Conditions:** Vegetation changes and forage availability can impact livestock farming.

8. **Economic and Social Implications:**

   - **Income and Livelihoods:** Climate change can reduce farmers' incomes and disrupt rural economies. This can lead to the migration of people from rural to urban areas.
   - **Food Security:** Reduced agricultural productivity can contribute to food insecurity, especially in developing countries.

9. **Erosion and Soil Degradation:**

   - **Soil Erosion:** More intense rainfall events and droughts can lead to soil erosion, which degrades soil quality and reduces its capacity to support crops.

Efforts to mitigate and adapt to these challenges for spring maize production include developing and planting drought-resistant maize varieties, improving water management practices, using climate-smart agricultural techniques, and adopting flexible planting strategies for changing climate conditions. Additionally, promoting sustainable agriculture and reducing greenhouse gas emissions are essential components of addressing the long-term impacts of climate change on spring maize and agriculture as a whole (Ma et al., 2022; Saroj et al., 2018).

Maize, technically known as *Zea mays* L., is a key and widely grown grain crop that has been cultivated for thousands of years. Known by various names, such as corn in North America, maize has a remarkable impact on global agriculture, food security, and economic development. This introduction provides an overview of the critical features, historical significance, and modern uses of maize. Maize is native to the Americas and was first domesticated by indigenous peoples in modern-day Mexico thousands of years ago. It quickly became a fundamental staple food for many Native American civilisations, such as the Maya and the Aztecs. The crop's versatility and adaptability led to its spread throughout the Americas and played a crucial role in developing these ancient societies. Maize is a grass family (Poaceae) member characterized by its tall, sturdy stalks with long, ribbon-like leaves. It produces tassel-like male flowers at the top of the plant and female flowers, or ears, lower down on the stalk. Maize kernels, the plant seeds, are the primary edible part arranged in cob rows (Alam et al., 2020).

Varieties and Adaptability: Over time, maize has been bred into numerous varieties, each suited to different climates, growing conditions, and end uses. Some common types of maize include dent corn, flint corn, sweet corn, and popcorn. Maize is renowned for its adaptability, growing in various tropical and temperate climates. Maize has achieved remarkable global importance as a staple crop(Singh et al., 2018; Nephali et al., 2020; Ma et al., 2022; Bhupenchandra et al., 2022). It is the third most produced grain in the world, after wheat and rice. Maize serves multiple purposes, being used for human consumption, livestock feed, industrial products, and as a source of biofuels. Its versatility and high nutritional value make it a cornerstone of food security in many countries (Alam et al., 2020).

Industrial Uses: Beyond food, maize has extensive industrial applications. It produces various products, including cornstarch, corn syrup, and corn oil. Additionally, maize is a raw material for producing biodegradable plastics and ethanol, contributing to sustainable practices in various industries.

Food and Nutrition: Maize is a rich source of carbohydrates, dietary fibre, and essential nutrients, including vitamin C, thiamine, and folate. Its consumption can provide essential calories and nutrition, particularly in regions where it is a dietary staple.

Modern Challenges: While maize is a resilient and adaptable crop, it faces challenges in the context of climate change, with shifts in temperature and precipitation patterns affecting crop yields. Additionally, pests and diseases threaten maize production, necessitating ongoing research and innovation (Sanp & Singh, 2018). The timing of sowing or planting dates significantly influences the growth which include overall development influence the yield of spring maize (*Zea mays* L.) crops. These effects vary depending on geographic location, climatic conditions, and specific maize varieties, but several common impacts are associated with different sowing dates (Sharma & Saxena, 2002).

1. **Yield Variation:**

    - **Early Sowing:** Early planting of spring maize typically results in more extended growing periods, allowing the crop to reach maturity before adverse weather conditions, such as drought or excessive heat. This often leads to higher yields and better grain quality.

    - **Late Sowing:** Delayed planting, on the other hand, may shorten the growing season, reducing the time available for maize to develop fully. Due to reduced grain filling time, late-sown maize crops may experience yield losses (Khan et al., 2002).

2. **Climate Variability:**

    - **Temperature Impact:** Sowing dates are critical in avoiding extreme temperatures during critical stages of maize growth. Early sowing can help prevent high temperatures during pollination and grain-filling, which can negatively affect yield. Late sowing may expose maize to the risk of frost damage at the end of the growing season.

    - **Rainfall Timing:** Different sowing dates can impact the alignment of crop development with regional rainfall patterns. Early-sown maize may coincide with rainy seasons, while late-sown maize may face drier conditions, increasing the risk of drought stress (Gurung et al., 2018).

3. **Pest and Disease Dynamics:**

    - **Early Sowing and Pest Management:** Early-sown maize may be exposed to different pest pressures compared to late-sown maize. Pest populations can vary based on sowing dates, requiring adjustments in pest management strategies.

- **Disease Risks:** Late-sown maize may be at a higher risk of certain diseases, as it may be more susceptible to pathogens present in the environment during the cooler, wetter periods of the growing season (Dahmardeh, 2010).

4. **Weed Management:**

   - **Weed Competition:** Sowing dates can affect weed pressure. Early-sown maize may face increased competition from weeds that germinate and are established more quickly, necessitating effective weed management practices.

5. **Quality Attributes:**

   - **Grain Quality:** Sowing dates can impact grain quality attributes such as kernel size, starch content, and nutrient composition. Early-sown maize may have an advantage in achieving desirable grain quality characteristics (Buriro et al., 2015).

6. **Adaptation to Local Conditions:**

   - **Local Adaptation:** The optimal sowing date for spring maize can vary significantly by region and even within microclimates. Local knowledge and adaptation to specific conditions are essential for maximizing yield and quality.

7. **Management Decisions:**

   - **Resource Allocation:** Sowing dates can influence resource allocation decisions. For example, early-sown maize may require more irrigation or fertilizer inputs to maximize its potential, whereas late-sown maize may benefit from strategies to accelerate growth (Amjadian et al., 2013).

The choice of sowing dates for spring maize is crucial in mitigating environmental stress and maximizing crop productivity. Different sowing dates can help spring maize adapt to a region's specific climatic conditions and challenges(Singh et al., 2018; Bhupenchandra et al., 2022; Malik et al., 2020; Kaya, Ashraf, and Sonmez 2018; Bibi and Rahman 2023;

Singh et al., 2022). Here is an exploration of the importance of varying sowing dates to mitigate environmental stress: Selecting the correct sowing date allows farmers to align maize growth with the availability of critical resources like water and sunlight. This helps optimise the use of these resources and reduce stress on the crop. Sowing dates can help maize avoid exposure to extreme temperatures. Early sowing can prevent pollination and grain-filling stages from coinciding with periods of high heat, which can negatively impact yield and grain quality (Buriro et al., 2015).

1. **Risk Mitigation:**
   - Delayed sowing may be necessary to avoid late-season frost risks in regions prone to such conditions. It allows maize to reach maturity before the onset of freezing temperatures, reducing the risk of crop loss.
2. **Matching Rainfall Patterns:**
   - Sowing dates can be adjusted to better align with regional rainfall patterns. This ensures that maize crops benefit from adequate moisture during critical growth stages, reducing the risk of drought stress.
3. **Pest and Disease Management:**
   - Different sowing dates can influence the prevalence of pests and diseases. Timely planting can help avoid pest populations that peak later in the season, reducing the need for chemical interventions.
4. **Improved Weed Control:**
   - Early sowing can give maize a competitive advantage against weeds. The crop can establish itself before weeds become problematic, reducing the need for extensive and costly weed control measures.
5. **Quality Enhancement:**
   - The suitable sowing date can improve grain quality attributes such as size and starch content. This is especially important for maize used in food and industrial applications.

6. **Yield Maximization:**

    - By selecting the appropriate sowing date, farmers can optimize crop yield. Early sowing often leads to more extended growing periods and higher yields, while late sowing can be advantageous in avoiding certain risks, leading to more stable yields (Amjadian et al., 2013).

7. **Adaptation to Climate Change:**

    - With climate change leading to more significant weather variability, selecting sowing dates becomes even more critical. Farmers can adjust sowing dates to adapt to shifting weather patterns and mitigate potential losses (Meena et al., 2018).

8. **Increased Resilience:**

    - Varying sowing dates allows for flexibility in adapting to changing environmental conditions. This resilience helps mitigate the impacts of unpredictable climate events and contributes to more stable and sustainable maize production (Gurung et al., 2018).

Salicylic Acid and Mitigation of Environmental Stress

In a world increasingly challenged by climate change and its cascading impacts on agriculture, the quest for effective strategies to mitigate environmental stress on crops has taken on paramount significance. One such strategy garnered considerable attention is using salicylic acid (SA) as a plant growth regulator. Salicylic acid, a naturally occurring phytohormone, orchestrates plant responses to environmental stressors. This introduction delves into the nature of salicylic acid and its role in alleviating the adverse effects of environmental stress on plants (Li et al., 2017; Majeed et al., 2020; Zangani et al., 2023; Mahdieh et al., 2022; Elhamid and Sadak 2019; Yasir et al., 2021; Prakash et al., 2021)).

Salicylic Acid: A Natural Regulator of Plant Responses: Salicylic acid is a hormone known for its multifaceted role in signalling pathways regulating plant growth and development. It is involved in various physiological processes, including seed germination, flowering, and responses to environmental stressors. Although most renowned for its role in plant defence mechanisms against pathogens, because of its potential, SA has received increased study interest to mitigate the adverse impacts of abiotic stressors, such as drought, high temperatures, and excessive salinity (Rai et al., 2020).

The Mechanisms of Salicylic Acid Action: The effects of salicylic acid are mediated through intricate biochemical and molecular processes within plants. SA acts as a signal molecule, initiating a cascade of responses that help plants withstand environmental stress. These responses often include (Rai et al., 2018):

- **Activation of Antioxidant Systems:** Salicylic acid can activate antioxidant enzymes like catalase and superoxide dismutase (SOD). This enhanced antioxidant activity helps plants cope with oxidative stress, a common consequence of various environmental stressors.
- **Reduction of Oxidative Damage:** SA has been shown to reduce oxidative damage to plant cells by mitigating lipid peroxidation and stabilising cellular membranes. This is crucial for maintaining the structural integrity of plant tissues under stress.
- **Maintenance of Photosynthesis:** Salicylic acid can help preserve photosynthetic activity, even under adverse environmental conditions. This is vital for ensuring the plant's energy production and growth.
- **Regulation of Stomatal Closure:** SA can influence stomatal behaviour, regulating the plant's water use efficiency and helping to manage water stress during periods of drought.
- **Modulation of Gene Expression:** Salicylic acid can influence the expression of stress-responsive genes, promoting the synthesis of stress-related proteins and other molecules that aid in stress tolerance.

The Promise of Salicylic Acid in Agriculture: Salicylic acid's potential to mitigate environmental stress on crops offers a promising avenue for sustainable agriculture. By harnessing the plant's natural defence mechanisms, SA-based treatments can enhance crop resilience, reduce yield losses, and improve the overall quality of agricultural products. As the world grapples with the increasing challenges of climate change and environmental stressors, understanding the role of salicylic acid and its application in crop management becomes essential to modern agricultural strategies (Khan et al., 2013; Naseem et al., 2020; Ghazi 2017; Yadav et al., 2018; Fahad and Bano 2012; Manzoor et al., 2015; Shemi et al., 2021)).

Sodium nitroprusside and its Importance in Mitigating Stress in Maize

In the face of mounting challenges posed by climate change, including shifting weather patterns, extreme temperatures, and environmental stressors, the quest for innovative strategies to bolster crop resilience and mitigate the impacts of these stressors has become increasingly imperative. Among the promising solutions that have emerged, the application of sodium nitroprusside (SNP), a chemical compound with multifaceted roles, has taken centre stage in enhancing the stress tolerance of maize and other crops. This introduction explores the nature of sodium nitroprusside and its pivotal role in mitigating stress when applied to maize (Prakash et al., 2021).

Sodium nitroprusside: A Versatile Compound with Plant Benefits: Sodium nitroprusside is a chemical compound with a rich history of medical, chemistry, and industry applications. Recently, it has gained recognition as a valuable tool in plant science. SNP contains nitric oxide (NO), a signaling molecule with critical functions in plants, including its role in mediating responses to environmental stress. As such, SNP has emerged as a powerful tool for researchers and farmers seeking to bolster crop health and resilience (Saroj et al., 2018). The Mechanisms of sodium nitroprusside Action: Using sodium nitroprusside in plants centres around its ability to release nitric oxide when it decomposes in plant tissues. Nitric oxide is a highly reactive molecule involved in diverse physiological processes within plants. Key mechanisms by which SNP can mitigate environmental stress in maize and other crops include (Rai et al., 2018):

- **Regulation of Stomatal Behavior:** SNP can influence the opening and closing of stomata, small openings on plant leaves. This regulation helps control the plant's water use efficiency and prevent excessive water loss, making it invaluable in managing drought stress. Scavenging Reactive Oxygen Species (ROS): sodium nitroprusside aids in reducing the damaging effects of oxidative stress. It acts as a scavenger of reactive oxygen species, such as superoxide and hydrogen peroxide, which accumulate in plants under stress.

- **Enhanced Antioxidant Systems:** SNP treatment can activate antioxidant enzymes, including superoxide dismutase (SOD) and catalase, vital in combating oxidative damage and maintaining cellular integrity. Improvement of Nutrient Uptake: SNP can enhance nutrient absorption by plants, facilitating the uptake of essential elements, such as iron, which is crucial for plant health and stress response.
- **Amelioration of Heat Stress:** SNP has demonstrated the potential to mitigate the effects of heat stress on maize by reducing heat-induced injury and preserving cellular membrane integrity.

The Promise of Sodium nitroprusside in Maize Agriculture: Sodium nitroprusside holds the promise of fortifying maize against the adverse effects of environmental stressors, including drought, salinity, extreme temperatures, and oxidative damage. Its application in maize cultivation can enhance crop resilience, reduce yield losses, and improve overall crop quality (Saroj et al., 2018).

Objectives-

1. To study of temporal dynamics and agrochemical on growth, yield and quality of hybrid maize,
2. to study impact of temporal dynamics and agrochemicals on nutrient uptake of hybrid maize,
3. to study the evaluation of salicylic acid and SNP on biochemical behavior of hybrid maize,
4. to study the impact of different treatments on the economic feasibility of the hybrid maize.

Review of Literature

The literature review is presented in section A. Bibliometric Analysis of Database of Scopus; B. Systematic Review.

Section A. Bibliometric Analysis: Search strategy and document evaluation A Comprehensive search of global literature was conducted in the Scopus database. Scopus was chosen because it is regarded as the most complete and extensively used database archiving literature in reviews and bibliometric analyses. The search keywords were "Cold, Heat and Agrochemicals" and the Second Search option was “Maize” And “Plant growth regulators*” covering long years. No language restriction was applied because most articles were written in English. The different search yield from 2022 to 23 after the post-COVID period has been represented in the figures (Figure 2.3). As part of the bibliographic analysis, we used the VOS viewer (Version 1.6.17) bibliographic metric tool to determine the co-authorship (country, organization), co-occurrence of keywords (most significant, all), and total number of links for each article (Figure 2.1& 2.2). The results of the studies have been visualised and mapped out so that potential gaps can be identified and knowledge limits can be highlighted about the regions where the studies have been carried out. The extraction and analysis of document metadata are essential to bibliometric analysis, a quantitative methodology used to evaluate the scholarly influence and patterns within academic literature. Document metadata encompasses organised and structured data about various documents, particularly research papers. This includes pertinent information such as the author's name, publication date, the journal or conference in which the document was presented, and associated citations. The metadata collection presents a valuable information source for scholars engaged in bibliometric research(Tufail et al., 2013; Tahjib-Ul-Arif et al., 2018; Zamaninejad et al., 2013; Moghaddam et al., 2011; Khan and Khan 2013; Miura and Tada 2014; Ijaz Ahmad et al., 2013). In bibliometric analysis, extracting metadata entails systematically gathering, refining, and structuring relevant information from an extensive collection of scholarly articles. This procedure enables researchers to generate extensive bibliographic databases, which form the basis for subsequent analysis. Tools and software are frequently employed to automate data extraction, improving efficiency and accuracy. After collecting metadata, the subsequent phase involves the commencement of the analytical process. Researchers can utilize this information to assess the productivity and influence of individual authors, research institutions, or journals. Citation networks can be established to discern influential papers and their interconnections, providing insights into research patterns and collaborative efforts. Furthermore, the utilization of metadata analysis facilitates the evaluation of scholarly outputs across temporal dimensions, thereby facilitating the identification of nascent domains of inquiry, monitoring the progression of particular disciplines, and appraising the influence of pivotal scholarly works. Scholars can assess academic publications' influence using diverse bibliometric measures, such as the h-index, impact factor, and citation counts.

Figure 2.1. The network of co-occurrence of all keywords on early sowing under different temporal dynamics based on Scopus literature search between 2009 to 2023

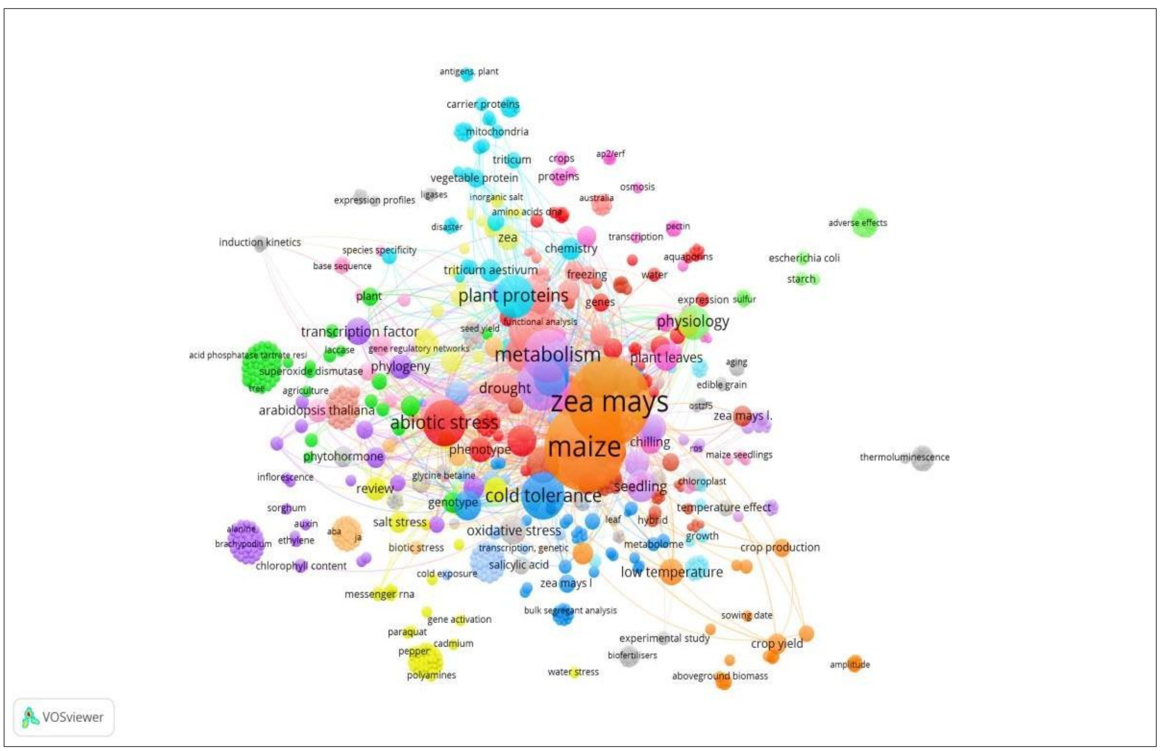


Figure 2.2. The network of co-occurrence of all keywords on late sowing under different temporal dynamics based on Scopus literature search between 2009 to 2023

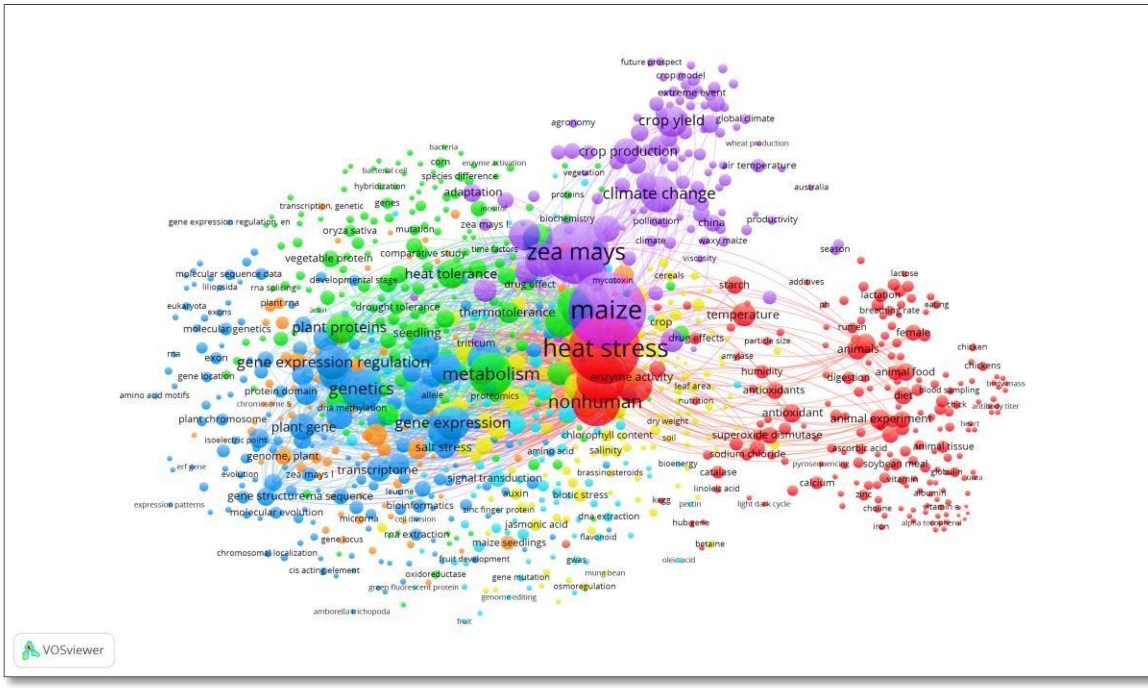
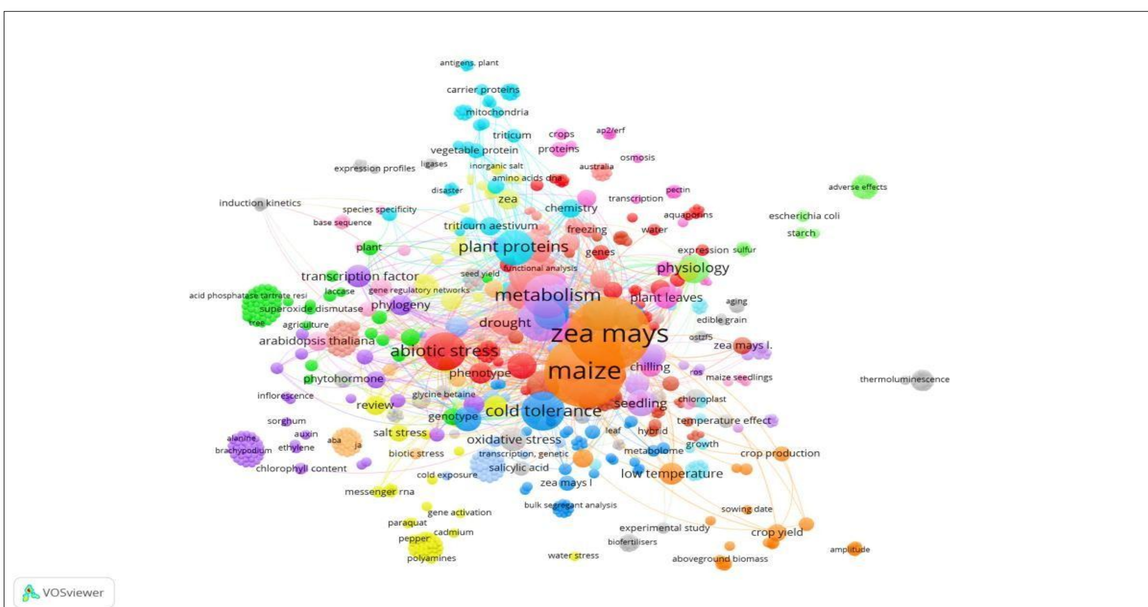


Figure 2.3. The network of co-occurrence of all keywords on agrochemicals under different temporal dynamics based on Scopus literature search between 2020-2023



B. SYTEMATIC REVIEW

Effect of climate change on maize production

The effect of climate change on maize production is a matter of global concern, as maize is a staple crop for many regions and plays a vital role in global food security. Climate change, driven by the increase in greenhouse gas emissions, is bringing about significant shifts in weather patterns and temperatures, which have several implications for maize cultivation. Here are the critical effects of climate change on maize production (IPCC, 2014; Rai et al., 2018; Braun et al., 2014; Salama 2019; Yasin et al., 2022; Hatfield and Prueger 2015; Ahmed et al., 2019; Warsame et al., 2023).

Najafi et al., 2018 state that high temperature includes heat stress: Rising temperatures, especially heatwaves, can expose maize crops to heat stress during critical growth stages, such as flowering and grain filling. This can reduce yields and affect grain quality.

Ahmed et al., 2018 state that erratic and unpredictable rainfall, including droughts, floods, and changes in precipitation patterns, leads to more frequent and severe droughts in some regions. Drought stress can decrease maize yields, impacting food security and income. In other areas, climate change can bring about heavy and erratic rainfall, causing flooding. Excessive moisture can damage maize plants and lead to waterlogged soils, impeding root growth and nutrient uptake in India.

Wu et al., 2021 state that erratic weather patterns can disrupt the optimal timing for planting, which is crucial for maize development. Late plantings can reduce the growing season and, consequently, yields. Unpredictable Harvests: Changing climate conditions can make predicting harvest times challenging, impacting farmers' labour and resource planning.

Increased Pest and Disease Pressure: Climate change can alter the distribution and behaviour of pests like corn borers and aphids, leading to increased pest pressure on maize crops. Changes in temperature and humidity can influence the prevalence and distribution of diseases like maize rust and northern corn leaf blight (Ahmed et al., 2020).

Erosion: More intense rainfall and droughts can contribute to soil erosion, deleting soil quality and reducing its capacity to support maize crops. (Warsame et al., 2023).

Reduced Yields: Climate change-related stressors can lead to reduced maize yields, affecting food production and potentially contributing to food shortages. Elevated carbon dioxide levels can minimize nutrient content in some maize varieties, impacting nutritional value (Alam et al., 2018).

Yasin et al., 2022 state that changes in rainfall patterns and increased evapotranspiration due to higher temperatures can lead to water scarcity, especially in regions where maize relies on rainfed agriculture. Maize production may require more energy and resources to adapt to changing conditions, impacting production costs.

Puglia et al., 2021 state that reduced maize production can lead to food shortages, increased prices, and challenges for vulnerable populations that depend on maize as a dietary staple. To address these challenges, farmers and agricultural communities need to adapt to changing climate conditions. This may involve using drought-resistant maize varieties, improved water management practices, sustainable farming techniques, and early warning systems for extreme weather events. Additionally, policies to reduce greenhouse gas emissions are essential to mitigate the long-term impacts of climate change on maize and agriculture.

The impact of various planting dates on maize production

The choice of sowing dates significantly influences maize production, including its morphological, biochemical, and yield attributes. Other sowing dates can lead to variations in growth and development, affecting the overall crop performance. Here is an overview of the effects of different sowing dates on spring maize (Gurung et al., 2018):

Buriro et al., 2015 examined that different sowing dates of maize affect the other morphological parameters of maize, directly influencing the maize production. Due to the extended growing period, early sowing dates typically result in taller maize plants. Late sowing may lead to shorter plants as the growing season is shortened. Early-sown maize often exhibits larger leaf areas, enhancing photosynthesis and plant growth. Sowing date affects root development. Early sowing allows for more profound and extensive root systems to access soil nutrients and water better in India (Ishfaq Ahmad et al., 2020; Wu et al., 2021; Najafi et al., 2018; Pachauri et al., 2014; Alam et al., 2020; Khan and Khan 2013; Yousafzai et al., 2002).

Dahmardeh 2010 states that early-sown maize usually has higher chlorophyll content, indicating better photosynthetic activity. Late-sown maize may experience reduced chlorophyll levels. Lipid peroxidation, an indicator of oxidative stress, may be lower in early-sown maize due to better stress management.

Salma et al., 2019 investigated the effect of different sowing dates on maize production and states that early-sown maize tends to exhibit higher membrane stability, indicative of better cell integrity and stress resistance. Sowing date can influence the levels of metabolites such as sugars, starch, proteins, and reducing sugars, which are essential for plant growth and yield.

Buriro et al., 2015 investigated how different sowing affects maize yield and grain quality. Also, they stated that early-sown maize often produces longer cobs, which can result in higher grain yield. The sowing date influences the number of cobs per plant, with early sowing generally leading to a more significant number. The number of kernels per cob is typically higher in maize planted early, contributing to increased yield. Early sowing generally results in higher grain yields than late sowing due to the extended growing period and favourable weather conditions during critical growth stages.

Miura et al., 2014 found the effect of foliar application of salicylic acid and sodium nitroprusside on maize growing in abiotic stress. It is important to note that the specific results of different sowing dates can vary by region, climate, and local conditions. The choice of sowing date should consider local climate patterns, frost dates, and the availability of resources like water and nutrients. Maize varieties with different maturities may also respond differently to sowing date variations.

Hatfeld et al., 2015 examined that optimising sowing dates is critical to climate-smart agriculture. Farmers must balance the risk of exposure to adverse weather conditions with the potential benefits of early planting for enhanced growth and yield. Additionally, advancements in crop breeding and agronomic practices offer opportunities to improve the resilience and productivity of spring maize under varying sowing conditions.

Rani et al., 2016 an experiment was conducted to assess the effect of two sowing dates (D1: August 1st and D2: August 15th), mulching (Mo: no mulch and M1: straw mulch @6 t ha-1), and three irrigation levels (IW/CPE = 0.50 (I1), 0.75 (I2), and 1.00 (I3)) on maize growth, yield, and water use efficiency during kharif 2010 in PAU, Ludhiana. The grain yield for the 1st August planted crop (46.0 qha-1) was much greater than that of the 15th August sown crop (33.6 qha-1), possibly owing to the higher 1000 grain weight. Such studies can be extremely useful in managing maize growth, yield, and water-use efficiency under changing climatic circumstances.

Effects of application of salicylic acid on maize production under different temporal dynamics

Applying salicylic acid (SA) in maize cultivation can significantly affect morphological, biochemical, and yield parameters, especially under different sowing dates. Here is an overview of the effects of SA on maize when sown under varying planting dates:

Morphological Parameters

Nephali et al., 2020 state that SA can promote greater plant height in maize, mainly when applied to early-sown crops. The hormone's impact on stem elongation and internodal length can lead to taller plants. Maize plants treated with SA may exhibit an increase in leaf area due to enhanced leaf expansion. This can contribute to improved photosynthesis and overall growth. The effect can be more pronounced in crops sown early.

Mandal et al., 2023 investigated that SA can stimulate root growth, particularly in young maize plants. This can lead to more extensive and efficient root systems, aiding nutrient and water uptake. Early-sown maize treated with SA may benefit from better-developed roots in Pune, India.

Biochemical Attributes

Ahmad et al., 2013 shows that the effects of application of SA-treated maize often show higher chlorophyll content. This indicates increased photosynthetic activity, which can enhance the plant's ability to convert light energy into chemical energy, especially in crops sown early. As a signalling molecule, SA can help reduce lipid peroxidation, indicating lower oxidative stress levels. This mainly protects the plant's cell membranes and overall integrity.

Rai et al., 2018 state that the application of SA's impact on membrane stability is often positive, indicating improved cell integrity and stress resistance. Early-sown maize treated with SA may exhibit more stable cell membranes under stress conditions in Uttar Pradesh, India. SA can influence the levels of various metabolites, including sugars, starch, proteins, and reducing sugars. These changes can impact nutrient availability and energy reserves for plant growth and development.

Yield Attributes

Braun et al., 2014 investigated that under different temporal dynamics, the application of SA could mitigate abiotic stress. Maize cobs treated with SA may be longer, particularly in early-sown crops. This can result in a higher number of grains and increased yield potential. SA can enhance the number of cobs per plant, mainly when applied to early-sown maize. This can contribute to a higher overall grain yield.

Khan et al., 2013 state that the application of SA increased the yield of maize by enhancing the yield-attributing characters. The number of kernels per cob typically increases in SA-treated maize, especially in early-sown crops. This results in higher grain yield due to increased kernel production. Maize treated with SA, mainly when sown early, often exhibits higher grain yields. The extended growing period and enhanced photosynthesis contribute to increased yield potential.

It is important to note that the effectiveness of SA treatment may vary based on environmental conditions, maize varieties, and local factors. Farmers should consider the specific needs of their crops and the local climate when deciding on the timing and dosage of SA application. The effect of salicylic acid (SA) on yield attributes, such as cob length, the number of cobs, and kernel number, when applied to maize sown under different planting dates, is influenced by the complex interaction of SA, planting dates, and environmental conditions. Here is an overview of the potential effects:

Zamaninejad et al., 2013 did an experiment that was carried out using a Randomized Complete Block Design (RCBD) as a Split Plot with three replications. Drought tension treatments included stress at the 10-12 leaf stage, stress during flowering and grain filling, and salicylic acid treatments at 0, 0.5 and 1.5-mM concentrations. According to the variance analysis results, drought stress significantly reduced kernel yield, row no per ear, kernel no per row and cob diameter, and ear length. Stress resulted in the highest and lowest kernel yields at the 10-12 leaf stage (7.1 ton/ha) and the blooming stage (4.7 ton/ha), respectively. SA for Early Sowing: Maize that is seeded early and treated with SA might produce longer cobs. Early sowing provides a longer growing season, and SA can enhance vegetative growth, which may lead to more extensive and extended cobs. Late Sowing with SA may have a shorter growing season, and the effect of SA on cob length might be less pronounced compared to early-sown maize. However, SA can still contribute to increased cob length under certain conditions.

Moghaddam et al., 2011 did an experiment in which the interactive effects of drought stress and SA were studied on the growth, forage, and grain yield of maize hybrid in India. Maize sown early and treated with SA has the potential to produce a higher number of cobs per plant. The extended growing period and SA's influence on branching and tillering can increase cob numbers. Late-sown maize may have fewer cobs compared to early-sown maize. While SA can promote branching and tillering, the shorter growing season might limit the number of cobs produced.

Shemi et al., 2021 experimented with the relative efficacy of foliar applications of salicylic acid (SA), zinc (Zn), and glycine betaine (GB) on morphology, relative water content (RWC), antioxidant enzyme activities, reactive oxygen species (ROS) along with yield attributes of maize plants exposed to two soil water conditions was investigated. Early-sown maize treated with SA often exhibits a higher kernel number per cob. Combining an extended growing season, enhanced photosynthesis, and optimized plant health contributes to excellent kernel production. Kernel number in late-sown maize may still benefit from SA treatment, but the potential increase might be limited due to the shorter growth duration. Late sowing can reduce the time available for kernel development.

It is important to emphasize that the effects of SA on yield attributes may vary depending on multiple factors, including the specific maize variety, local climate conditions, soil quality, and SA application method and dosage. Additionally, the choice of sowing date is a critical factor that interacts with SA treatment. While SA can promote growth and yield attributes, its effectiveness is generally more pronounced in early-sown maize due to the extended growing season.

Biochemical Attributes

The effect of salicylic acid (SA) on various biochemical attributes in maize, including chlorophyll content, lipid peroxidation, membrane stability, amylose and starch levels, sugar content, protein content, reducing sugars, and the activity of antioxidant enzymes like catalase and superoxide dismutase (SOD), as well as the level of hydrogen peroxide, can vary based on the timing of sowing. Here is an overview of how SA can influence these biochemical attributes under different sowing dates:

Ahmad et al., 2013 did an experiment in which spring maize seedlings were given foliar sprays of ascorbic acid (AsA), salicylic acid (SA), and hydrogen peroxide (H_2O_2) at the third leaf stage. Foliar treatment lengthened the shoots and roots, associated with higher levels of 13 superoxide dismutase (SOD), chlorophyll, and nutrients. Shoot length was discovered to be related to shoot N, P, and K content, as well as leaf SOD and chlorophyll levels. Maize sown early and treated with SA will likely exhibit higher chlorophyll content. SA can enhance chlorophyll synthesis and protect against chlorophyll degradation, increasing photosynthetic activity. Late-sown maize may still benefit from SA treatment, but the potential increase in chlorophyll content might be limited due to the shorter growing season.

Tahijib et al., 2018 investigated that early-sown maize treated with SA will likely reduce lipid peroxidation. As an antioxidant, SA can help protect cell membranes from oxidative damage, lowering lipid peroxidation. Late-sown maize may also experience decreased lipid peroxidation with SA treatment, but the impact may be influenced by the limited growing season and potential stress factors.

Tufail et al., 2013 did an experiment in which they found that SA treatment in early-sown maize can enhance membrane stability. The extended growing season and SA's protective effects improve membrane integrity. SA can still positively impact membrane stability in late-sown maize, but the product might be less pronounced due to the shorter growth duration.

Fahad and Bano 2012 did an experiment in which maize sown early and treated with SA may exhibit increased amylose and starch levels. SA can promote carbohydrate accumulation due to enhanced photosynthesis. Late-sown maize may still benefit from SA regarding amylose and starch levels, but the shorter growing season may limit the overall impact.

Manzoor et al., 2015 investigated that early-sown maize with SA treatment can potentially have higher sugar content, as SA enhances photosynthesis and increases sugar production. Late-sown maize may also experience increased sugar content with SA application, but the effect might be less significant due to the shorter growth period.

Ghazi et al., 2017 found that early-sown maize treated with SA will likely have higher protein content and reduced reducing sugars. SA can support protein synthesis and reduce sugar accumulation, improving nutritional quality. Late-sown maize may still benefit from SA regarding protein and reducing sugars, but the impact may be less pronounced due to the limited growing season.

Yadav et al., 2018 did an experiment in which they found that early-sown maize with SA treatment is likely to have higher catalase and SOD activity and lower hydrogen peroxide levels in Inida. SA can enhance the activity of antioxidant enzymes, reducing oxidative stress. Late-sown maize may still experience improvements in catalase and SOD activity with SA. Still, the impact on hydrogen peroxide levels may vary due to the shorter growing season and potential stress factors.

The effect of sodium nitroprusside (SNP) on morphological parameters, biochemical attributes, and yield attributes in maize can vary based on the timing of sowing. Here is an overview of how SNP may influence these aspects when applied to maize under different planting dates:

Morphological Parameters

Prakash et al., 2021 did an experiment in which they found that maize sown early and treated with SNP is likely to exhibit enhanced morphological parameters, such as increased plant height, larger leaf area, and more extensive root development. The longer growing season and SNP's influence on plant growth can contribute to these improvements. Late-sown maize treated with SNP may still benefit from improved morphological parameters, but the potential increase might be limited due to the shorter growing season.

Biochemical Attributes

Saroj et al., 2018 state the effects of exogenous nitric oxide on paddy and maize plants in salty soil at different times. Sprays of sodium nitroprusside (SNP), a source of nitric oxide (NO), were administered to the leaves either before (control), during (50, 100, 150 M), or after (saline stress) application. SNP treatment, especially in early-sown maize, may increase chlorophyll content, indicating enhanced photosynthetic activity and improved growth. As a nitric oxide donor, SNP can help reduce lipid peroxidation and protect cell membranes, particularly in early-sown maize. SNP can promote membrane stability, particularly in early-sown maize, contributing to better cell integrity and stress resistance. SNP treatment can influence the levels of metabolites such as sugars, starch, proteins, and reducing sugars, which can impact nutrient availability and energy reserves for plant growth and development.

Yield Attributes

Naseem et al., 2020 state that applying SNP in early-sown maize will likely result in longer cobs, potentially leading to increased grain yield. Maize treated with SNP, especially when sown early, may exhibit more cobs per plant due to enhanced branching and tillering. SNP-treated maize, mainly when sown early, often shows more kernels per cob, increasing grain yield. Maize treated with SNP, especially when sown early, often exhibits higher grain yields due to the extended growing season, improved photosynthesis, and optimized plant health. It is essential to consider that the effectiveness of SNP treatment may vary depending on environmental conditions, maize variety, soil quality, local climate, and SNP application method and dosage. The choice of sowing date also plays a significant role in the interaction with SNP treatment, as early sowing generally provides a longer growing season for maize, which can enhance the potential benefits of SNP on morphological, biochemical, and yield attributes. The impact of sodium nitroprusside (SNP) on yield attributes in maize, such as cob length, the number of cobs, and kernel number, can vary depending on the timing of sowing. Here is an overview of how SNP might influence these yield attributes when applied to maize under different planting dates:

Mahdieh et al., 2022 did an experiment in which maize sown early and treated with SNP will likely result in longer cobs. The longer growing season allows for extended cob development, and SNP may contribute to cob elongation. Late-sown maize treated with SNP may still experience increased cob length, but the effect might be less pronounced due to the shorter growth season.

Ramadan et al., 2019 did an experiment in which maize sown early and treated with SNP is likely to produce more cobs per plant. The extended growing season and SNP's influence on branching and tillering can increase cob numbers. Late-sown maize may have fewer cobs than early-sown maize, but SNP treatment can still promote branching and tillering, contributing to more cobs.

Yasir et al., 2021 did an experiment in which they found that early-sown maize treated with SNP often exhibits a higher kernel number per cob. Combining an extended growing season, enhanced photosynthesis, and optimized plant health contributes to excellent kernel production. Kernel number in late-sown maize may still benefit from SNP treatment, but the potential increase might be limited due to the shorter growth duration. Late sowing can reduce the time available for kernel development. Various factors, including the maize variety, local climate conditions, soil quality, SNP application method and dosage, and the overall health of the maize plants, can influence the specific effects of SNP on these yield attributes. Early sowing generally provides a longer growing season, which can enhance the potential benefits of SNP treatment on yield attributes.

The effect of sodium nitroprusside (SNP) on various biochemical attributes in maize, such as chlorophyll content, lipid peroxidation, membrane stability, amylose and starch levels, sugar content, protein content, reducing sugars, and the activity of antioxidant enzymes like catalase and superoxide dismutase (SOD), as well as the level of hydrogen peroxide, can vary based on the timing of sowing. Here is an overview of how SNP may influence these biochemical attributes when applied to maize under different planting dates:

Habib et al., 2021 state that maize sown early and treated with SNP will likely exhibit higher chlorophyll content. SNP can enhance chlorophyll synthesis and protect against chlorophyll degradation, increasing photosynthetic activity in India. Late-sown maize may still benefit from SNP treatment concerning chlorophyll content, but the potential increase might be limited due to the shorter growing season. Early-sown maize treated with SNP is likely to have reduced lipid peroxidation. SNP acts as a nitric oxide donor and can help protect cell membranes from oxidative damage, resulting in lower lipid peroxidization. Late-sown maize may also experience decreased lipid peroxidation with SNP treatment. Still, the impact may be influenced by the limited growing season and potential stress factors.

Singh et al., 2022 state that when the foliar spray of SNP was done in early-sown maize, it can enhance membrane stability. The extended growing season and SNP's protective effects improve membrane integrity. SNP can still positively impact membrane stability in late-sown maize in India, but the effect might be less pronounced due to the shorter growth duration.

Zanganni et al., 2023 investigated that when maize is sown early and treated with SNP, it may exhibit increased amylose and starch levels. SNP can promote carbohydrate accumulation due to enhanced photosynthesis. Late-sown maize may still benefit from SNP regarding amylose and starch levels, but the shorter growing season may limit the overall impact.

Majeed et al., 2020 stated that when maize is sown with foliar, SNP treatment can have higher sugar content, as SNP enhances photosynthesis, resulting in increased sugar production. Late-sown maize may also experience increased sugar content with SNP application, but the effect might be less significant due to the shorter growth period. Early-sown maize treated with SNP will likely have higher protein content and reduced reducing sugars. SNP can support protein synthesis and minimize sugar accumulation, improving nutritional quality. Late-sown maize may still benefit from SNP in terms of protein and reducing sugars, but the impact may be less pronounced due to the limited growing season.

Kaya et al., 2018 state that early-sown maize with SNP treatment will likely have higher catalase and SOD activity and lower hydrogen peroxide levels. SNP can enhance the activity of antioxidant enzymes, reducing oxidative stress. Late-sown maize may still experience improvements in catalase and SOD activity with SNP. Still, the impact on hydrogen peroxide levels may vary due to the shorter growing season and potential stress factors.

Harmeet et al., 2017 performed an experiment in Research Farm, Punjab Agricultural University, Ludhiana, which was put out in a split plot design with four replications with three dates of planting viz. February 10, February 20, and March 2 in main plots and seven foliar sprays. 1% KNO3 at tassel initiation, 2% KNO3 at tassel initiation, 1% KNO3 at tassel initiation + another spray after one week, and 2% KNO3 at tassel initiation + another spray after one week, Water stress during tassel initiation, tassel initiation plus one more spray after one week, and control (no spray) in subplots. Spring maize production and yield parameters were significantly affected by different planting dates and foliar water and KNO3 sprays.

Various factors, including the maize variety, local climate conditions, soil quality, SNP application method and dosage, and the overall health of the maize plants, can influence the specific effects of SNP on these biochemical attributes. Early sowing generally provides a longer growing season, which can enhance the potential benefits of SNP treatment on these biochemical attributes. Farmers should carefully consider local conditions, including frost dates, temperature, and precipitation patterns, when determining the optimal sowing date for maize. Additionally, SNP application should be conducted with attention to recommended dosages and timing to maximize its potential benefits on maize biochemical attributes.

The application of salicylic acid (SA) and sodium nitroprusside (SNP) can influence seed quality parameters in maize, including NPK content (nitrogen, phosphorus, and potassium), as well as crude fibre content. The effects of SA and SNP on seed quality parameters may vary depending on the timing of sowing. Here is an overview of how SA and SNP may influence these parameters when applied to maize under different planting dates:

Gopalakrishnan et al., 2022 investigated that maize sown early and treated with SA and SNP may show reduced crude fibre content in the seeds. SA and SNP can influence the plant's metabolic pathways, potentially leading to lower fibre content in the roots. Late-sown maize may also experience a reduction in crude fibre content with SA and SNP treatment. Still, the impact may be influenced by the limited growing season and potential stress factors in Gujarat, India.

Various factors, including the maize variety, local climate conditions, soil quality, SA and SNP application methods and dosages, and the overall health of the maize plants, can influence the specific effects of SA and SNP on seed quality parameters. Early sowing generally provides a longer growing season, which can enhance the potential benefits of SA and SNP treatment on seed quality parameters. Farmers should consider their local conditions, including frost dates, temperature, and precipitation patterns, when determining the optimal sowing date for maize (Mandal et al., 2023). Additionally, SA and SNP application should be conducted with attention to recommended dosages and timing to maximize their potential benefits on maize seed quality parameters, including NPK and crude fibre content.

MATERIALS AND METHODS

The study was conducted during the spring seasons of 2022 and 2023, titled "**Evaluation of the Quantitative and Qualitative Response of Hybrid Maize (*Zea mays* L.) under Different Agrochemicals and Temporal Dynamics."** The research was conducted at the School of Agriculture, Lovely Professional University (LPU) in Phagwara, Punjab. The main emphasis of this chapter is to provide a detailed account of the criteria used and the methodologies utilized in conducting experimental research to assess treatments during the whole period of the inquiry.

3.1 SITE OF EXPERIMENT

The study was conducted on an open field inside the School of Agriculture at Lovely Professional University (LPU) in Phagwara, Punjab, from 2022 to 2023. According to the data obtained from Google Maps, the farm is situated at a latitude of 31.244604 N and a longitude of 75.701022 E, with an elevation of 232 meters above sea level.

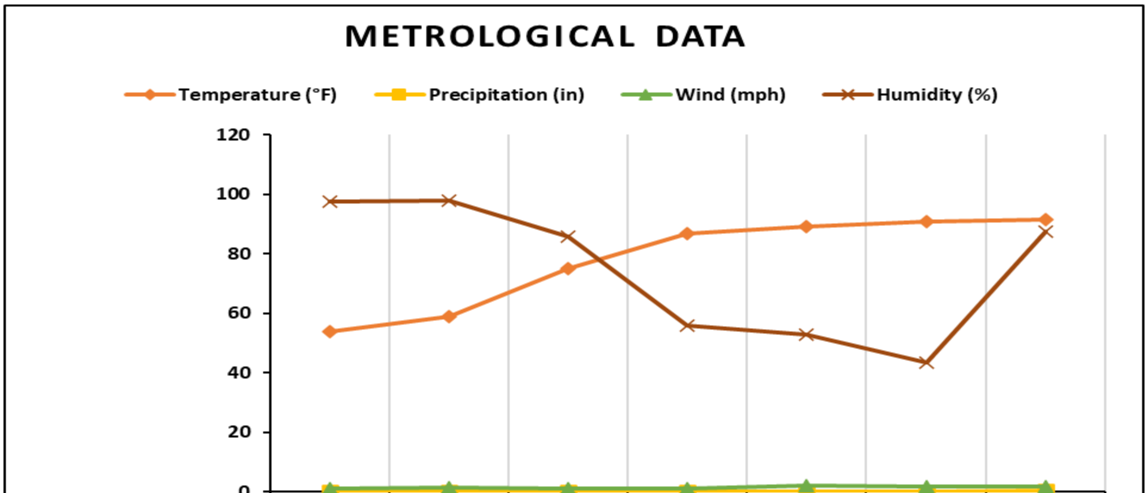
Fig. 3.1: Experimental farm, School of Agriculture

Source: Google Earth

3.2 CLIMATIC CONDITION

Phagwara is located in the northern area of India, especially inside the Trans-Gangetic plains area, an agroclimatic zone. The area under consideration is situated in the lower foothills of the Himalayan range, including a rich plain between the Beas and Sutlej rivers. Phagwara is a pivotal access point to the Himalayan area, with an average elevation of 243 meters (767 feet). January is often acknowledged as the month with the lowest temperatures, while June is widely accepted as associated with the highest temperatures. Furthermore, June has an average precipitation level of 686 millimeters. The customary timeframe for the onset of the monsoon typically occurs from late June to early July, persisting until the beginning of September. The average precipitation level is estimated to be about 200 mm. In the present period, the highest recorded temperature reaches 45ºC in June, and the lowest temperature drops to 0ºC in January. The initial relative humidity is measured to be 33% and exhibits a rise to 64% throughout the duration, including May to September.

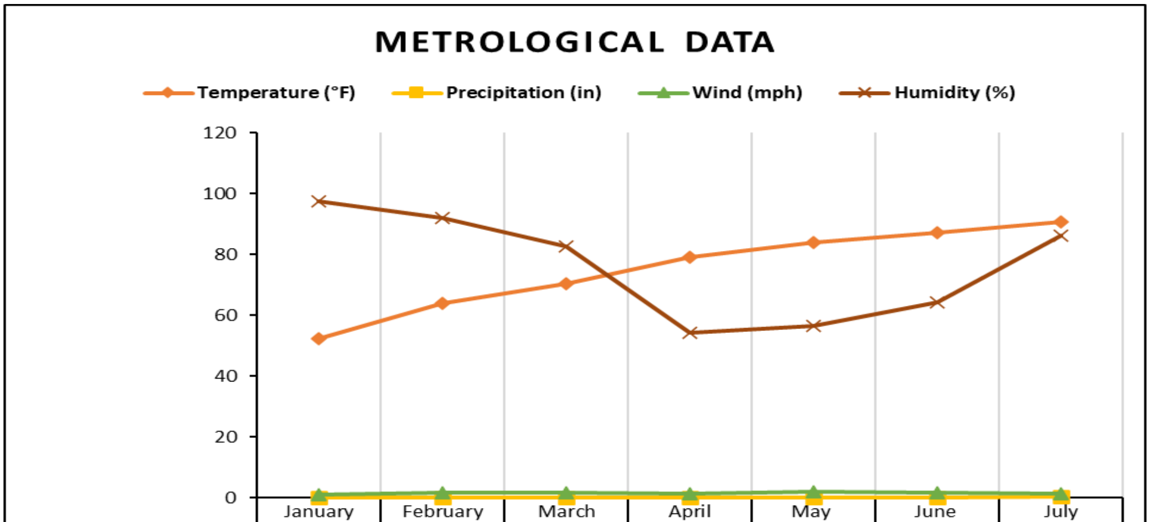
Fig. 3.2.1. Standard Metrological monthly average weather data from January to July 2022



	January	February	March	April	May	June	July
Temperature (°F)	53.78	58.91	74.93	86.86	89.03	90.8	91.61
Precipitation (in)	0.18	0.02	0	0	0.11	0.07	0.52
Wind (mph)	1.26	1.42	1.25	1.21	2.2	1.83	1.64
Humidity (%)	97.7	97.9	85.8	55.8	53	43.3	87.6

(Source: https://www.wunderground.com)

Fig. 3.2.2. Standard Metrological monthly average weather data from January to July 2023



	January	February	March	April	May	June	July
Temperature (°F)	52.42	64.07	70.55	78.96	83.79	87.32	90.58
Precipitation (in)	0.01	0	0.14	0.02	0.06	0.16	0.62
Wind (mph)	1.07	1.7	1.69	1.5	2.01	1.84	1.44
Humidity (%)	97.4	92	82.8	54.2	56.7	64.3	86.3

(Source: https://www.wunderground.com)

3.3 EXPERIMENTAL FIELD SOIL

Soil samples were collected from the designated field using a zig-zag approach at 0-15 cm depth before field preparation to assess the soil's chemical and nutritional composition. The collected sample brought to the lab and left for the shade dry for overnight. Then after that soil sample was sieved to avoid the litters and stones in sample. Then representative sample was obtained from primary and secondary soil sample. Table 3.3.1 displays the primary physio-chemical characteristics of the soil.

Table 3.3.1. Chemical and nutrient status of soil in 2022 and 2023

S. no.	Particulars	2022	2023	Method
		Value		
1.	Soil pH	8.41	8.54	Glass electrode pH meter (Sparks 1996)
2.	Electrical Conductivity (ds/m)	0.727	0.656	Electrical Conductivity (Sparks 1996)
3.	Organic carbon	0.49	0.52	Wet digestion method (Walkley and Black)
4.	Available Nitrogen (kg/ha)	149	151	Alkaline potassium per magnate method
5.	Available Phosphorus (kg/ha)	16.65	15.87	0.5 N $NaHCO_3$ extractable Olsen method
6.	Available Potassium (kg/ha)	165.7	159.8	Flame photometer method (Jackson 1973)

3.4 Procedures for chemical properties and nutrient status

3.4.1. Soil pH (Sparks 1996)

- A quantity of 5 grams of soil was put into a beaker with a volume of 50 milliliters.
- Subsequently, 25 milliliters of distilled water were added to the beaker, followed by shaking the mixture for 30 minutes.

- After the 30-minute interval, a sample was taken from the mixture and analyzed using a pre-calibrated pH electrode, with the resulting reading recorded.

3.4.2. Electrical conductivity (Sparks 1996)

- A quantity of 5 grams of soil was put into a beaker with a volume of 50 milliliters.
- Subsequently, 25 milliliters of distilled water were added to the beaker. The mixture was then vigorously shaken for a duration of 30 minutes.
- After this period, a mixture sample was taken and assessed using a pre-calibrated electrical conductivity (EC) electrode. The resulting reading of the sample was recorded.

3.4.3. Available nitrogen (kg/ha) (Subbaiah and Asija 1956)

- A quantity of 20 grams of dried soil was placed into the distillation flask of a micro-Kjeldahl distillation assembly.
- The distillation flask should be filled with 100 ml of a 0.32% $KMnO_4$ solution and 25 ml of a 2.5% NaOH solution.
- A volume of 150 mL was extracted from the conical flask and supplemented with 10 mL of boric acid, followed by 3-4 drops of a mixed indicator.
- Place the conical flasks holding boric acid at the lowermost position of the receiving tube inside the distillation assembly.
- Approximately 100 milliliters of distillate were obtained. The hue that was once pink transitioned to a shade of blue. The boric acid was subjected to back titration using a 0.02N sulphuric acid (H_2SO_4) solution. After the experiment, the blue hue transformed into a pink shade.

3.4.4. Available phosphorus (Olsen et al., 1954)

- One gram of soil was placed into a conical flask with a 250-milliliter volume. Subsequently, 20 milliliters of a 0.5 molar sodium bicarbonate ($NaHCO_3$) solution were added to the flask.
- The flask was then agitated for 30 minutes using an electric shaker. The resultant suspension was filtered using Whatman No.1 filter paper.
- Similarly, a substance-free solution was prepared. A 5 mL extract was obtained and mixed with 5 mL of a 1.5% ammonium molybdate solution.
- An additional 10 mL of distilled water was added to the mixture. A volume of 1 ml of stannous chloride was introduced into the solution, developing a blue colour.
- Subsequently, the absorbance measurement was obtained using a spectrophotometer calibrated at a wavelength of 560 nanometers.

3.4.5. Available potassium (Jackson 1973)

- A quantity of 5 grams of desiccated soil was transferred into a conical flask with a volume of 150 milliliters.
- Subsequently, 25 milliliters of a solution with 1 normal (1N) concentration of ammonium acetate were added.
- The sample should be agitated for five minutes using a mechanical shaker. Subsequently, the resulting suspension should be filtrated using Whatman No. 1 filter paper.
- The extracted sample was then put into a beaker, and a 5 ml aliquot was selected for dilution. Subsequently, the measurement was conducted using a flame photometer.

3.4.6. Organic carbon (Walkley and Black 1934)

- A dried soil sample weighing 1g was carefully put into a 500ml conical flask.

- Subsequently, 10 ml of a 1 N $K_2Cr_2O_7$ solution and 20 ml of concentrated H_2SO_4 solution were added to the flask.

- Thoroughly combine the ingredients, and after that, allow for 30 minutes of waiting. The solution should be diluted by adding 200 ml of distilled water and 10 ml of H3PO4.

- To initiate the titration process, it is recommended to include 7-8 drops of diphenylamine indicator into the solution.

- Subsequently, titration may be carried out using a 0.5 N Ferrous Ammonium Sulphate (FAS) solution.

- The solution devoid of any substance was made similarly. The termination point was designated with the colour green.

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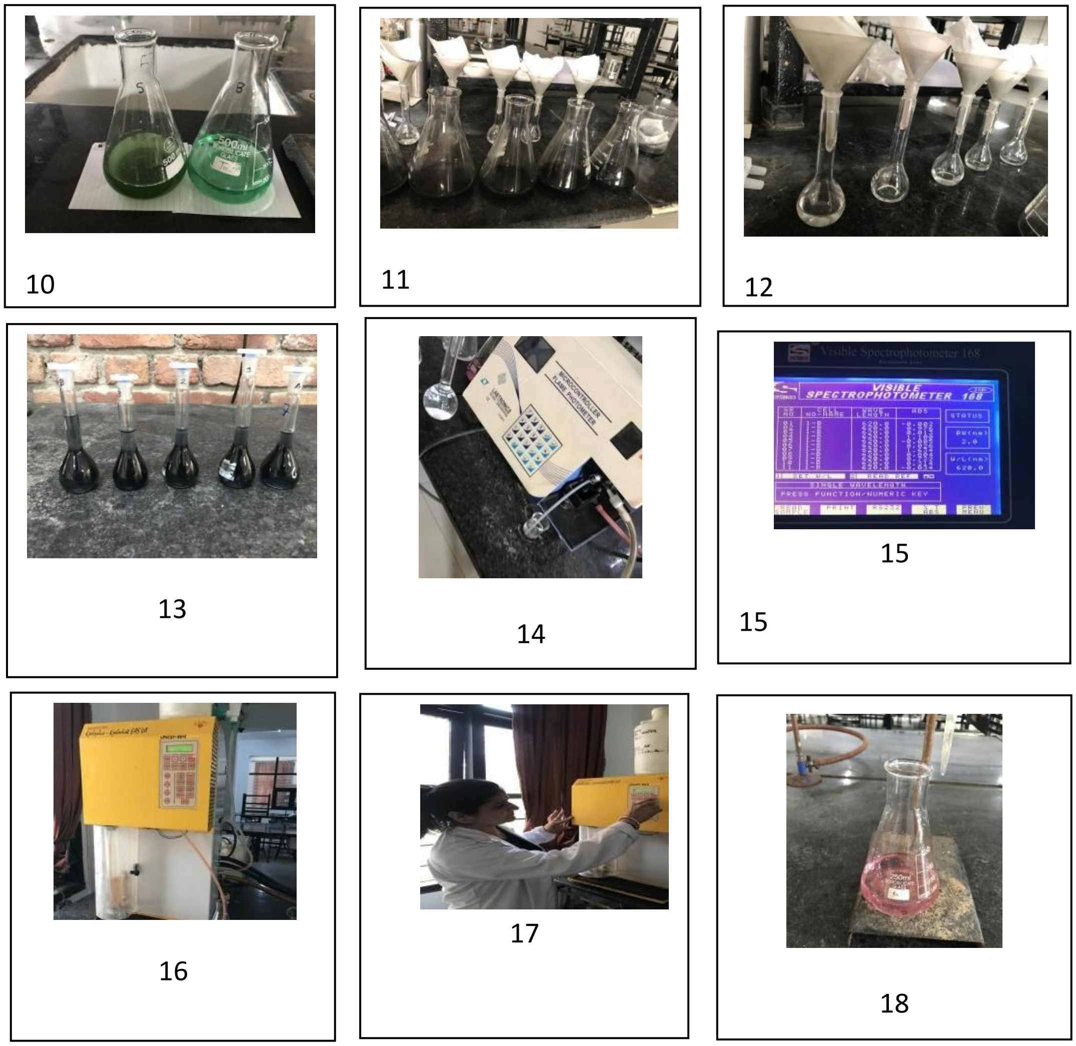


Figure 3.4 Estimation of chemicals properties and nutrient status of soil

Where fig 1. Represents primary soil sample; 2. Sieving of soil sample; 3. Representative soil sample; 4. Weighing of soil sample; 5. Sample prepared; 6. Soil sample after 30 minutes;7. Reading in pH meter; 8. Reading EC meter; 9. Soil sample for organic carbon; 10. Sample after titration; 11.sample for phosphorus; 12. Sample after filtration; 13. Volume make up to 25 ml; 14. Reading of potassium in flame photometer; 15. Spectrophotometer reading; 16 and 17. Sample in digestion unit for Nitrogen; 18. Final sample after titration

3.4.7. Statistical analysis

The field and biochemical data were subjected to statistical analysis using analysis of variance (ANOVA). The data was analyzed using STATISTIX 10 software, using Duncan's multiple range test (DMRT) with a least significant difference (LSD) at a significance level of $p<0.05$.

3.5 Source of seed and agrochemicals

The seeds of maize, precisely the PMH-10 variety, exhibit a state of being free from diseases and possessing good health. The sourced of variety was obtained from Punjab Agriculture University, Ludhiana, while the agrochemicals were sourced from the laboratory located in Block 57-501 of Lovely Professional University's School of Agriculture (Fig. 3.5.1 & Fig. 3.5.2).

Figure 3.5.1. Source of seed

Figure 3.5.2. Source of agrochemicals

3.6 TREATMENTS DETAILS

The field experiment was carried out at the agricultural field of the School of Agriculture, Lovely Professional University, located in Jalandhar, Punjab. The investigation focused on a specific Maize variety, PMH-10, obtained from Punjab Agriculture University in Ludhiana, Punjab. The aggregate gross plot area of the field amounted to 1200 square meters. The dimensions of the site were 70 meters in length and 17 meters in breadth. The gross subplot size of the subject was measured to be 5x5= 25 m^2, whereas the net subplot area was recorded as 5x4=20 m2. The experiment had three distinct sowings conducted at intervals of 15 days. The first seeding occurred after January, the optimal sowing was performed in the middle of February, and the late planting was executed during the first week of March. Salicylic acid and sodium nitroprusside, which are agrochemicals, were applied using a knapsack sprayer 15 and 45 days after sowing (DAS). The measurements were conducted at three distinct time points, namely 30 DAS, 60 DAS, and 90 days after sowing (DAS). The experimental details are shown in Table 3.6.1.

Table 3.6.1: Experimental details

Location	**Research farm of LPU, Jalandhar**
Crop	Maize
Design	Split–Plot Design
Treatment	12
Replication	3
Total no. of plot	36
Gross sub-plot size	5 x 5 m =25 m^2
Net sub-plot size	5 x 4 m = 20 m^2
Spacing	60 x 20 cm
Year	2022 and 2023 *Spring* season
Agrochemicals Spray time	At 15 and 45 DAS
Method of application	Foliar Spray [with suitable sprayer]

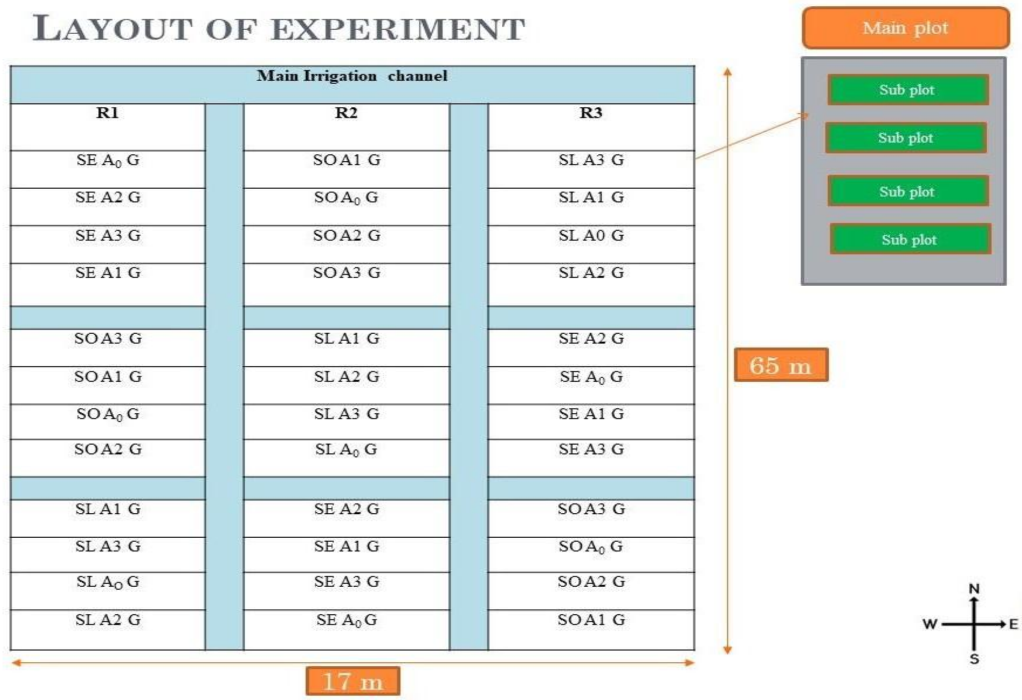
3.7 DESIGN OF EXPERIMENT

The experiment was structured using a Split Plot Design. The primary element in this study is the sowing dates, whereas the secondary component is the use of various agrochemicals, including the control group. The experiment had three replications for each treatment, resulting in 36 plots. The specific specifics of each treatment may be seen in Table 3.7.1.

Table 3.7.1. Treatments details of experiment

Name of treatments	Symbol used for each treatment
(Sowing date)	
Early sowing	SE
Optimum sowing	S0
Late sowing	SL
(Agrochemical)	
Control	A0
Sodium nitroprusside (250 µM/L)	A1
Salicylic acid (150mg/L)	A2
Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	A3

Figure: 3.7.1. Layout of experiment



3.7.2 Varietal description

PMH-10: Punjab Agriculture University released it in 2015, and it requires good management and irrigated conditions during the Spring Season in Punjab. It is moderately tolerant to high-temperature stress and has attractive orange flint grains (Fig. 3.7.2).

Figure 3.7.2. Source of Seed

3.8 Agronomic practices

Cultural practices were implemented by the prescribed package and methods of Punjab Agricultural University (PAU), Ludhiana, to ensure optimal crop development. Plant protection measures were implemented based on the specific requirements.

3.8.1. Field allotment

The experiment field was allotted for the 2022 and 2023 spring seasons on the School of Agriculture, Lovely Professional University farm.

3.8.2 Preparation of field

The allotted experiment field was first prepared with a tractor rotavator, followed by primary tillage using a disc harrow. Subsequently, secondary tillage was conducted, along with the necessary levelling procedures. The process of layout delineation was undertaken to prepare the plots (Fig. 3.8.2).

Figure 3.8.2. Field preparation

3.8.3 Date of sowing

The three date of sowing was selected to expose the maize plant to different environmental conditions. The first sowing was done at the end of January, optimum sowing was done in the second week of February, and late sowing was done in the first week of March (Fig. 3.8.3).

Figure 3.8.3. Date of sowing

3.8.4 Preparation of agrochemicals

The known concentration of Salicylic acid and sodium nitroprusside was prepared in the laboratory and transferred to a plastic bottle to take to the field for spray (Fig. 3.8.4).

Figure 3.8.4. Preparation of agrochemicals

3.8.5 Application of agrochemicals

The prepared agrochemicals were sprayed on plants at four leaves and eight leaf stages with a suitable sprayer (Fig. 3.8.5).

Figure 3.8.5. Application of agrochemicals

3.8.6 Germination test

In controlled settings, a laboratory experiment was done at laboratory 57-501 to assess the seed germination percentage. The filter paper was evenly distributed on the petri dish's surface, followed by applying moisture by adding water. Subsequently, ten seeds were dispersed and later concealed under an additional petri plate. The germinated seeds were tallied after seven days to determine the germination percentage (Fig.3.8.6).

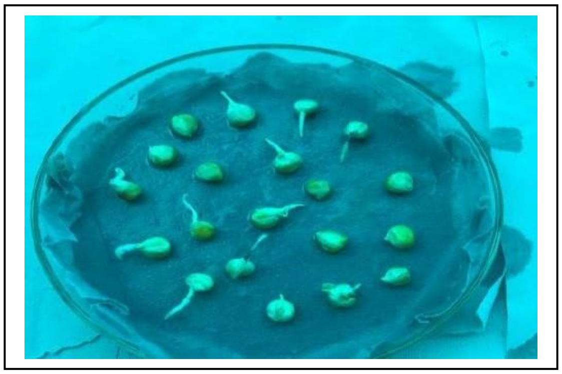


Figure 3.8.6. Germination test was conducted in lab

3.8.7 Moisture and temperature recorded

The soil moisture was recorded with the help of a moisture meter, and soil temperature was recorded with a soil thermometer before and after the sowing till the germination took place (Figure 3.8.7).

Figure 3.8.7. Moisture and temperature recorded

3.8.8 Sowing: Before sowing seed, treatment was done with one of the most essential fungicides, i.e. bavistin, at 1 g/kg of seeds. After the treatment, two seeds per hill were sown on ridges at 20 cm spacing and light irrigation was done at early sowing was done at the end of January, optimum sowing was done in the second week of February, and late sowing was done in the first week of March (Figure 3.8.8).

Figure 3.8.8. Sowing

3.8.9 Irrigation

The irrigation operation was promptly carried out after the sowing process, with subsequent attention given to the daily scheduling of irrigation needs. Irrigation was administered at varying intervals by prevailing weather conditions. Water is an essential need for the survival of all living organisms on the planet, including agricultural plants. Consistent watering is necessary to ensure the preservation of crop development and growth (Fig. 3.8.9)

Figure 3.8.9. Irrigation

3.8.10 Scare reflective tape

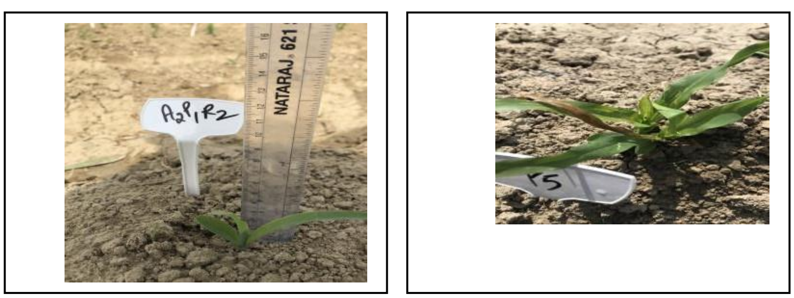
There was a bird attack on emerging seedlings. They uprooted the emerging seedling and eat the seed to protect it. Reflective scare tape was tied in the field (Fig.3.8.10).

Figure 3.8.10. Scare reflective tape

3.8.11 Tagging

After the germination, plant density was maintained, and tagging was done in each plot by selecting the ten random plants from the net plot area. The morphological and yield attributes data was recorded from the tagged plants. Fresh-weight and dry-weight plants were taken from the gross plot area for the biochemical analysis and left for the destructive samples (Fig. 3.8.11).

Figure 3.8.1. Tagging



3.8.12 Weeding

Weeding was conducted regularly, accompanied by herbicides, due to the high prevalence of weeds in the field. Atrazine and Sempra were applied at the prescribed dosage to manage weed growth (Fig.3.8.12).

Figure. 3.8.12. Weeding

3.8.13 Insecticide control

Fall armyworm infestation emerged in the maize, prompting regular intervals of spraying emamectin benzoate and chlorpyriphos as control measures (Fig.3.8.13).

Figure.3.8.13 Insecticide control

3.8.14 Harvesting

The maize harvesting process took place throughout July, using sickles to cut the plants after they had reached complete dryness and had a brownish colour. The moisture content of the grains at the time of harvesting was recorded at 13%. The manual harvesting process included using a sickle to gather the crops within a designated plot area of 1 square meter. Subsequently, the harvested crops were subjected to a sun-drying period lasting around 3 to 4 days. Following harvesting, it is necessary to detach the cobs from the stalks and then clean them by eliminating the husks and silk (Fig.3.8.14).

Figure.3.8.14. Harvesting

3.8.15 Drying

The corn cobs were subjected to a drying process under solar radiation for 3 to 4 days. Subsequently, the seeds were extracted from the cobs and subjected to further drying for further examination (Fig.3.8.15).

Figure. 3.8.15. Drying

3.9 Different observation was recorded

The recorded different observations were categorized into five phases, namely 30 days after sowing (DAS), 60 DAS, and 90 DAS. The following section provides a detailed account of the recorded observations about morphological parameters, biochemical characteristics, yield attributing parameters, quality parameters and economics analysis of whole experiment with the standard process used throughout the research.

3.9.1 MORPHOLOGICAL PARAMETERS

3.9.1.1 Plant height (cm)

Plant height Measurements were taken in identified plants 30 days, 60 days, and 90 DAS. The plants' height was measured using a measuring scale, from the last internode to the uppermost internode, or from the first emerging leaf to the plant's topmost leaf (Fig.3.9.1.1).

Figure.3.9.1.1 Plant height (cm)

3.9.1.2 Leaf number/plant

The leaf number per plant was recorded in tagged plants by counting the leaves from the top to the bottom, and the average value is considered the mean value in each treatment (Fig.3.9.1.2).

Figure. 3.9.1.2. Leaf number/plant

3.9.1.3 Internodal length (cm)

The parts of the stem between the nodes are called internodes. From one node to another, the length of the internodes was measured in each plant. The average intermodal length of all plants was used to determine the final intermodal length. Multiple internodes were seen in the Maize plants. Therefore, the internodal length was defined as the mean intermodal length (Fig.3.8.1.3).

Figure.3.9.1.3. Internodal length (cm)

3.9.1.4 Stem diameter (mm)

At 30, 60, and 90 days, we measured the diameter of the stem from its base to its apex using a digital Vernier calliper. The average diameter of the stems was determined and expressed in millimeters (Fig.3.9.1.4).

Figure.3.9.1.4. Stem diameter (mm)

3.9.1.5 Leaf area (cm^2)

Leaf area was measured using a leaf area metre at 30, 60, and 90 days after sowing (DAS), and the average leaf area in square centimetres was computed (Fig. 3.9.1.5).

Figure.3.9.1.5. Leaf area (cm^2)

3.9.1.6 Fresh weight (g)

At 30, 60, and 90 DAS intervals, fresh weight was measured using the weighing balance and determined in gram (Fig.3.9.1.6).

Figure. 3.9.1.6. Fresh weight (g)

3.9.1.7 Dry weight (g)

At different intervals of 30, 60, and 90, DAS samples were dried in a hot air oven at 150 ^{o}C for 72 hours, and after that, weight was recorded using a weighing balance in gram (Fig. 3.9.1.7).

Figure. 3.9.1.7. Dry weight (g)

3.9.1.8 Days to 50 % tasseling

At 60 DAS the days to 50% was recorded in different treatments in 1 m^2 area (Fig.3.9.1.8).

Figure.3.9.1.8. Days to 50 % tasseling

3.9.1.9 Plant population at physiological maturity (1000/ha)

During the physiological stage, the plant population within a designated region of 1 m^2 was quantified across several experimental treatments (Fig.3.9.1.9).

Figure.3.9.1.9. Plant population

3.9.1.10 Crop growth rate (CGR, g day^{-1} m^{-1})

CGR, or Crop Growth Rate, refers to the quantifiable augmentation in the mass of plant materials per unit area during a specific period. The calculation may be performed using the method proposed by Watson in 1952.

CGR= W2-W1/T2-T1

Where W2 is the dry weight of the plant at time T2, W1 is the dry weight of the plant at time T1.

3.9.1.11 Relative growth rate (RGR, g g^{-1} day^{-1})

The term was introduced by Williams in 1946. The term "total increase in dry weight of a plant at two intervals" refers to the cumulative growth in mass of a plant during a specific period. The expression may be represented as the ratio of a unit's dry weight to another unit's dry weight over time.

RGR= logeEW2- logeW1/T2-T1

3.9.1.12 Net assimilation rate (mg/cm^2/day)

The dry matter measurements obtained at various time intervals are used to compute the Net Assimilation Rate (NAR), as Watson (1952) outlined.

NAR= (W2-W1) (logeL2- logeL1)/(T2-T1) (L2-L1)

Where W2, W1 = dry weight of maize plant at T2, T1

3.9.1.13 Dry matter accumulation

The dry matter was calculated by measuring the fresh and dry weights at 30, 60, and 90 DAS intervals.

3.9.2 BIOCHEMICAL PARAMETERS

3.9.2.1 Chlorophyll content (mg g^{-1} fresh weight)

Principle: Chlorophyll is extracted using an 80% acetone solution, and its absorbance is then measured at wavelengths of 645nm and 663nm. The use of the absorbance coefficient determines the quantification of chlorophyll content.

Reagent: Acetone (80%, pre-chilled)

Procedure: A leaf sample weighing 100 mg was subjected to crushing using a solution consisting of 20 ml of acetone with an 80% concentration. The resulting supernatant was then carefully transferred to a centrifuge tube in preparation for centrifugation. Following centrifugation at a speed of 5000 revolutions per minute (rpm) for 10 minutes, the resulting supernatant was carefully transferred into a volumetric flask. The volume of the supernatant was then adjusted to 100 millilitres (ml) by adding 80% acetone. The spectrophotometer measured the absorbance at 645 and 663 nm wavelengths, using an 80% acetone blank as a reference. The chlorophyll content was quantified using the provided formula (Fig.3.9.2.1).

Chlorophyll ‗a (mg/g Fresh Weight) = 12.7(A663)-2.69(A645) x V/1000 x W; Chlorophyll ‗b' (mg/g Fresh Weight) = 22.9(A645)-4.68(A663) x V/1000 x W; Total chlorophyll (mg/g Fresh Weight) =20.2(A645) +8.02(A663)xV/1000xW

where V= Final volume of the extract, W= Initial Fresh weight of the leaves, and A absorbance atthe specific wavelength. The value is expressed as the mg/g fresh weight.

Figure 3.9.2.1 Estimation of chlorophyll content

3.9.2.2 Anthocyanin content (mg/g fresh weight)

Principle: Anthocyanin is extracted using an 80% acetone solution, and then, the extract anthocyanin's absorbance is quantified at a wavelength of 535 nm. The use of the absorbance coefficient determines the quantification of Anthocyanin content.

Reagent: Acetone (80%, pre-chilled)

Procedure: A leaf sample weighing 100mg was subjected to crushing using 20 ml of acetone solution with an 80% concentration. The resulting supernatant was transferred to a centrifuge tube in preparation for centrifugation. Following centrifugation at a speed of 5000 revolutions per minute (rpm) for 10 minutes, the resulting supernatant was carefully transferred to a volumetric flask. The volume of the supernatant was then adjusted to 100 millilitres (ml) by adding 80% acetone. The absorbance measurement was conducted at a wavelength of 535 nm using a spectrophotometer, with the 80% acetone blank serving as a reference. The use of the following formula determined the Anthocyanin content (Fig.3.9.2.2).

Figure.3.9.2.2. Anthocyanin content

Anthocyanin (mg/100g fresh weight) = absorbance at 535 nm x volume of extraction solutionx100/ wt. of sample in g x 98.2

3.9.2.2 Carotenoids content (mg/g fresh weight)

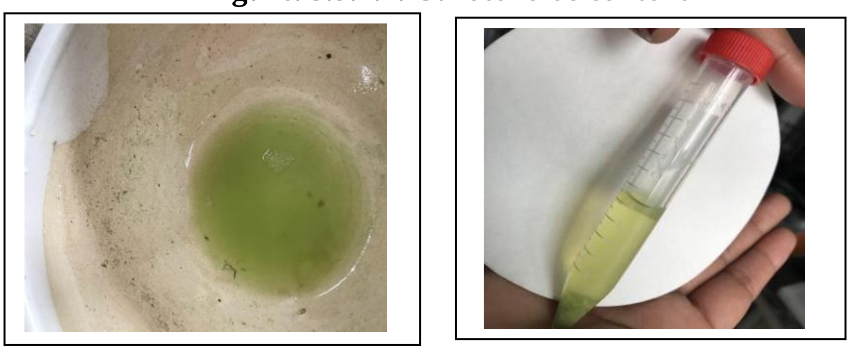
Principle: Carotenoids absorbance was measured at 450 nm after being extracted in 80% acetone. The amount of Carotenoids is calculated using the absorbance coefficient.

Reagent: Acetone (80%, pre-chilled)

Procedure: A leaf sample weighing 100mg was subjected to crushing using 20 ml of acetone solution with an 80% concentration. The resulting supernatant was transferred to a centrifuge tube in preparation for centrifugation. Following centrifugation at a speed of 5000 revolutions per minute (rpm) for 10 minutes, the resulting supernatant was carefully transferred into a volumetric flask. The volume of the supernatant was then adjusted to 100 millilitres (ml) by adding 80% acetone. The absorbance measurement was conducted at a wavelength of 420 nm using a spectrophotometer relative to an 80% acetone blank. The quantification of carotenoid content was determined using the following formula (Fig.3.9.2.2).

Amount of carotenoids in mg/g fresh weight = 4x OD x total sample volume, i.e. 100ml/ weight of plant tissue, i.e. 100 mg.

Figure. 3.9.2.2. Carotenoids content



3.9.2.3Total soluble sugar content (microgram/ml)

Principle: Total soluble sugar in a plant sample may be quickly and easily calculated using the Anthrone reaction. Furfural is produced through the dehydration of carbohydrates in concentrated H_2SO_4 . The 630 nm calorimetric measurement of the complex formed when furfural condenses with Anthrone reveals a blue-green hue.

Reagents

Ethanol (80%)

Anthrone reagent: Dissolve 200 mg anthrone in 100 ml of ice-cold 95% sulphuric acid. Prepare fresh before use.

Standard glucose: Dissolve 100mg of glucose in 100 ml of water to make stock; dilute 10 ml to 100 ml with distilled water as a working standard.

Procedure: We used 10 millilitres of ethanol to break down 100 milligrams of leaf. We next centrifuged the pulverized material for 15 minutes at 5000 rpm. After centrifugation, the supernatant was moved to a volumetric flask, and distilled water was used to adjust the volume to 100 ml. Add 6 millilitres of anthrone reagent to a separate test tube and 1 millilitre of extract. After 10 minutes in the water bath, the test tube was cooled under running water. A control sample was made similarly, but no leaf extract was included. A spectrophotometer reading of 620 nm was used to quantify the depth of blue. The standard curve was used to determine the sugar content (Fig.3.9.2.3).

Figure 3.9.2.3. Estimation of total soluble sugar

Standard Curve

Dissolve 10 mg of glucose in 100 ml of distilled water or dilute 10 ml of standard glucose stock with 100 ml of distilled water to create a working standard. Different concentrations of the sugar solution were made from this stock solution by placing 0.2 ml, 0.4 ml, 0.6 ml, 0.8 ml, and 1.0 ml of the stock solution into individual test tubes. Distilled water was used to bring the total amount of each test tube up to 3 ml, and then 6 ml of the anthrone reagent was added. After being placed in a water bath, they were boiled. After chilling the solution, the blue light's intensity at 620 nm was measured. The absorbance value was plotted against the sugar concentration in the solution to get the standard curve.3.9.2.4 Total Soluble Protein content (microgram/ml)

3.9.2.4. Total soluble sugar protein(microgram/ml)

Principle

The assay relies on the principle that, when Coomassie Brilliant Blue G-250 is dissolved in an acidic solution, its absorbance maximum shifts from 465 nm to 595 nm upon binding to proteins. This color change occurs because the anionic form of the dye is stabilized through both hydrophobic and ionic interactions. The efficiency of this experiment stems from the fact that a 10-fold change in concentration does not affect the extinction coefficient of the dye-albumin complex solution.

Reagents:

- Sodium phosphate buffer (pH 7.4)
- Solution A: Dissolve 13.9 grams (g) of 0.1 M sodium dihydrogen phosphate (NaH_2PO_4) in one liter (1000 ml) of distilled water to create the sodium phosphate buffer.
- Solution B (sodium phosphate buffer) was prepared by dissolving 26.82 grams of 0.1 M disodium hydrogen phosphate. (Na_2HPO_4) in distilled water until the final volume reached 1000 millilitres.

- Using a pH meter, we adjusted the final pH to 7.4 by combining solutions A and B in a 19:81 ratio.

Concentration of the dye: Coomassie brilliant blue G 250 (100 mg) should be dissolved in 95% ethanol (50 ml). Combine 100 ml of ortho-phosphoric acid with the mixture. The volume should be brought up to 200 ml with distilled water. The solution will be kept in the fridge for at least six months if stored in an amber container. I used a 1:4 ratio of distilled water to dilute the intense dye solution. If there is any sediment, filter it using Whatman No. 1 paper.

Procedure: The 100mg of plant material was transferred to a mortar and pestle for further processing. We put in the 10 ml of cold extraction. The cannon was placed in the ice bucket, and a fine slurry was created by cursing it with the pestle. The centrifugation process took 15 minutes and reached 15,000 rpm. 5 ml of the diluted dye, 2 ml of the leaf crude protein extract, and 8 ml of distilled water were combined, and the mixture was let to sit for at least five minutes and no more than thirty. When bound to proteins, the red dye takes on a blue hue. Using a spectrophotometer, determine the absorbance at 595 nm (Fig.3.9.2.4).

Figure 3.9.2.4. Estimation of protein content in maize leaf

Standard Curve

The Bovine Serum Albumin (BSA) used to make the standard curve ranged in volume from 0.1 to 1.0 ml. The absorbance value vs the sugar content in the solution was plotted against one another to generate the standard curve. Total soluble protein concentration is given in milligrams per milligramme of sample.

3.9.2.5 The determination of the maize leaf membrane stability index (MSI) and membrane injury index (MII)

Principle: Solute leakage, or electrolyte leakage, from cells, and the MSI can serve as indicators of membrane damage. The increased Electrolyte leakage induced by stress is indicative of potential damage to the plasma membrane.

Reagent: Distilled water

In a test tube with 10 ml of double-distilled water, we put 200 mg of leaves. They were cooked at 40 degrees Celsius for 30 minutes and 100 degrees Fahrenheit for 10 minutes. After that, an EC meter was used to measure the sample's electrical conductivity after it had been cooled in running tap water. The EC at 400°C is designated as C1, whereas the EC at 100°C is defined as C2. Following is the formula used to determine the MSI and MII (Fig.3.9.2.5).

MSI= 100 $[1 - C1/C2]$

MII = 100 $[C1\ /C2]$

Figure 3.9.2.5. Determination of membrane stability index and injury index

3.9.2.6 Lipid peroxidation [malondialdehyde (MDA) content (micromoles/g fresh weight) of maize leaf

Principle

Lipid peroxidation was determined by measuring the amount of MDA.

Reagents

a). Trichloroacetic acid (TCA) (0.1% w/v)

b). Thiobarbituric acid (TBA)

Procedure

Crushing 0.5 g of fresh leaves and adding them to 5 ml of trichloroacetic acid solution yielded a 5% yield. After removing the solids, the supernatant was centrifuged at 12,000 rpm for 15 minutes. The supernatant was then transferred to fresh test tubes, and 0.5% thiobarbituric in 20% TCA was added to the original test tubes before they were boiled at 96 0C for 25 minutes. After centrifuging at 10,000 rpm for 5 minutes, the test tubes were placed on an ice tray to cool (Fig.3.9.2.6).

Figure 3.9.2.6. Estimation of lipid peroxidation [malondialdehyde (MDA) content]

To account for background turbidity, we subtracted the absorbance at 600 nm from the absorbance at 532 nm using a blank solution of 0.5% TBA in 20% TCA.

Calculation of MDA-TBA complex

Based on the extinction coefficient of 155 M^{-1} cm^{-1}, the quantity of MDA-TBA complex (red pigment) may be estimated. The levels of MDA were measured and recorded. The data was shown as moles of malondialdehyde per gram of fresh weight (FW).

Figure 3.9.2.9 Estimation of catalase activity

Principle: Enzyme performance is measured by calculating how much H_2O_2 is left behind after the completed reaction.

Reagent

1. Phosphate buffer (0.1 M) and maintain pH 6.4% (v/v) H_2O_2

Procedure:

Using a mortar and pestle and an ice cube tray, 100 mg of the leaf was crushed in 5 ml of 0.1 M phosphate buffer. In a cooling centrifuge machine, the crushed material was spun for 20 minutes at 10,000 rpm and 4 ºC. The catalase enzyme activity was determined. Using 0.1 ml of plant extract, 0.1 ml of 1% H_2O_2, and 2.6 ml of 0.1 M phosphate buffer.

Figure 3.9.2.9 Estimation of catalase activity

Similarly, a blank was created by replacing the enzyme extract in a reaction mixture with 0.1 M phosphate buffer. Absorbance was measured using a spectrophotometer with a UV probe at 240 nm. Using an extinction value of 43.6 for H_2O_2 breakdown, the enzyme activity per gram of fresh weight was calculated (Fig.3.9.2.9).

EU mg^{-1} protein = δ A 240/min × 1000 / 43.6 × mg protein ml^{-1} reaction mixture

The EU was reported both as a function of fresh weight (per g) and protein (specific activity) (per mg).

3.9.2.10 Total amylose in the leaf of maize

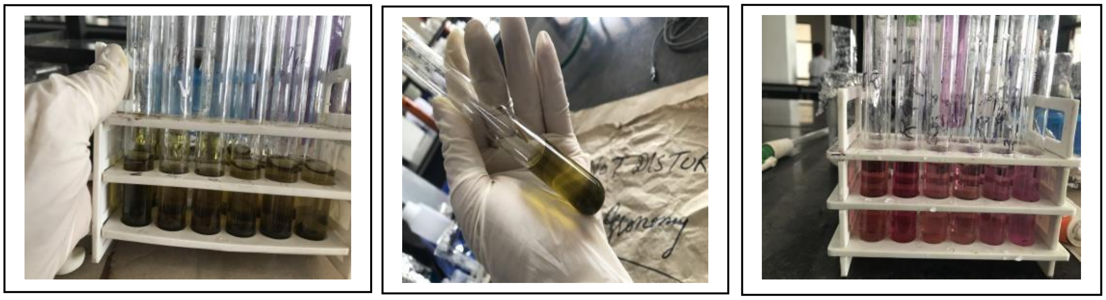
Principle: The D-glucose units in amylose are joined together by -1, 4 glycosidic linkages, making it a linear polymer. When combined with iodine, amylose becomes purple. It is found in coiled form, with six glucose residues per coil. Calorimetric analysis reveals a blue complex produced when amylase's helical coils take up iodine at a wavelength of 590 nm.

Reagents

1. 1N NaOH
2. 0.1% Phenolphthalein indicator
3. 80 % Ethanol
4. Iodine reagent: Dissolve 1g of iodine and 10 g of KI in water and make it up to 500ml.
5. Standard amylose: 100mg amylase in 10 ml of 1N NaOH and makeup to 100ml with water (1 mg/ml).

Procedure: Mixed 100 mg of powdered dry material with 1 ml of 80% ethanol and 10 ml of NaOH. The ingredients were well combined and let to sit at room temperature for a full day. The next step was to mix 2.5 ml of extract with 20 ml of distilled water and an indicator concentration of 0.1% Phenolphthalein (three drops). A new shade of pink was created. 0.1 N HCl was added to the mixture to remove the last traces of pink. One millilitre of iodine reagent was added, and the remaining volume was brought up to 50 millilitres with distilled water. The spectrophotometer reading for absorbance was obtained at 590 nm. One millilitre of iodine reagent was added to fifty millilitres of distilled water and used to draw a standard curve for the quantity of amylase in the sample, which ranged from 0.2 to 1.0 milligrams (Fig.3.9.2.10).

Figure.3.9.2.10. Total amylose in the leaf of maize



Standard curve of Total amylose

Amylose (100 mg) was dissolved in 1N NaOH (10 ml) and then diluted to 100 ml with distilled water (1 mg/ml). Different concentrations of the sugar solution were made from this stock solution by placing 0.2 ml, 0.4 ml, 0.6 ml, 0.8 ml, and 1.0 ml of the stock solution in individual test tubes. These test tubes were filled to a final capacity of 1 ml with pure water. The amylose standard curve was generated by relating the absorbance at 590 nm (y-axis) to the amylose concentration (x-axis).

3.9.2.11 Total starch content in the leaf of maize

Principle: Sugars are first removed using 80% alcohol, then starch is extracted using perchloric acid from the sample. Hydrogenation of starch to glucose and dehydration to hydroxymethylfurfural occur in a hot acidic media, respectively. When combined with Anthrone, this chemical produces a green pigment.

Reagents

1. Anthrone reagent: Dissolved 200mg of anthrone in 100ml of ice-cold 95% sulphuric acid.

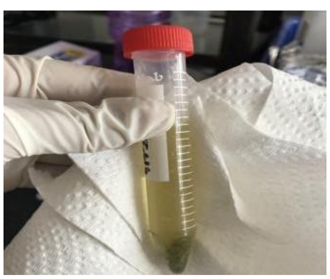
2. 80% Ethanol

3. 52% Perchloric acid

4. Standard glucose: Stock-dissolve 100mg of glucose in 100ml water, working standard 10 ml of the stock diluted to 100ml with distilled water.

Procedure: The sugars were extracted from 500 mg of leaf sample by homogenizing it in hot 80% ethanol. The extract went through a centrifuge for 20 minutes at 5000 rpm. The solids remaining after the supernatant had been removed were saved. This residue was rinsed extensively with hot 80% ethanol until further treatment with anthrone reagent failed to change its colour. The leftovers are dried thoroughly in a water bath. 5.0 ml of water and 6.5 ml of perchloric acid at 52% concentration were added to the remaining substance. A cooling centrifuge spun the mixture at 5000 rpm at 0°C for 20 minutes. It was decided to save the obtained supernatant. New perchloric acid was used to redo the extraction. The amount of supernatant received was enough to fill 100 ml. The remaining volume was brought up to 1 ml by Pipetting off the remaining 0.1 or 0.2 ml of supernatant. The anthrone reagent was then added in a volume of 4 ml. Then, it was placed in a pot of boiling water and left there for 8 minutes. After bringing the solution to room temperature, the spectrophotometer read a peak intensity of green to dark green at 630 nm. Using a conventional graph, we were able to determine the concentration of glucose in the sample. The starch concentration was calculated by multiplying the result by 0.9 (Fig.3.9.2.11).

Figure.3.9.2.11. Total starch content in the leaf of maize



Preparation of the standard curve for estimation of total starch

Dissolve 100 mg of glucose in 100 ml of distilled water, or dilute 10 ml of standard glucose stock with 100 ml of distilled water to get a working standard. Different concentrations of the sugar solution were made from this stock solution by placing 0.2 ml, 0.4 ml, 0.6 ml, 0.8 ml, and 1.0 ml of the stock solution in individual test tubes. Distilled water was used to bring the total amount of each test tube up to 3 ml, and then 6 ml of the anthrone reagent was added. After being placed in a water bath, they were boiled. After chilling the solution, the blue light's intensity at 620 nm was measured. Plotting the absorbance value (y-axis) vs the concentration of sugar (x-axis) to generate the standard curve. Total starch content was calculated by multiplying the result by a factor of 0.9.

3.9.2.12 The amylopectin in the leaf of maize using the method introduced by Sadasuvam and Manickam (1992).

The amount of amylopectine was calculated by subtracting the amylose concentration from the starch concentration.

$$\text{Amount of amylopectin (mg)} = \text{Amount of Starch(mg)} - \text{Amount of Amylose(mg)}$$

3.9.2.13 Total reducing sugar content in the leaf of maize using the method introduced by Somogyi, M. (1952).

Principle: When heated with alkaline copper tartrate, the reducing sugar converts the copper from the cupric to the cuprous state, forming cuprous oxide. Arsenomolybdic acid may transform molybdic acid to molybdenum blue by reacting with cuprous oxide.

Reagent

1. Alkaline copper tartrate

(a) Dissolve in an alkaline Mix 20 grams of anhydrous sodium sulphate, 2.5 grams of potassium sodium tartrate, 2 grams of sodium bicarbonate, and 80 millilitres of water until the mixture reaches 100 millilitres in volume.

(b) In a small amount of distilled water, dissolve 15 grams of copper sulfate.

To create up to 100 ml, add one drop of sulphuric acid.

Before using, combine 4 ml of (b) with 96 ml of solution (a).

Dissolve 2.5 g of ammonium molybdate in 45 ml of water to make the arsenomolybdate reagent. Combine the sulfuric acid (2.5 ml) with the water. Disodium hydrogen arsenate (0.3 g) should then be added. The components were combined and incubated at 37 degrees Celsius for 24 to 48 hours. The standard stock solution is 100 milligrammes of glucose in

100 millilitres of sterile water. To create a working standard, we diluted 10 ml of standard stock (100 g/ml) with 100 ml of distilled water.

Procedure: 100 mg of plant material was homogenized in 10 ml of 80% ethanol. The supernatant was recovered after centrifuging homogenates at 5000 rpm for 20 minutes. Evaporation on a water bath removed the supernatant that had been collected. There was an addition of 10 ml of water. Pipetting out aliquots of 0.1 ml into each test tube followed. Distilled water was used to get the final volume to 1 ml. 1 ml of the alkaline copper tartrate reagent was poured into the test tube. The test tubes were boiled for 10 minutes in a water bath at a rolling boil. Once the test tube had cooled down, 1 ml of arsenomoblybdate reagent was added. The last step was to dilute the solution to 10 ml using double-distilled water. The 620-nanometer wavelength was used to measure the blue colour's absorption. The enzyme extract was left out of the blank, which consisted of distilled water and the rest of the reagent. Total reducing sugar content was determined using a standard curve plot (Fig.3.9.2.13).

Fig: 3.9.2.13 Total reducing sugar content in the leaf of maize

3.9.2.14 The total non-reducing sugar content in the leaf of maize using the method introduced by Somogyi, M. (1952).

Total non-reducing sugar content was determined by reducing sugar content from total soluble sugar. To get the non-reducing sugar, we subtract the total sugar by the amount of reducing sugar (mg).

3.9.2.15 Chlorophyll index [SPAD UNIT]

Chlorophyll was measured using a SPAD meter at 30, 60, and 90 DAS. Chlorophyll concentration may be determined by measuring the same leaf thrice with the SPAD meter and averaging the results (Arregui, 2006) (Fig.3.9.2.15).

Figure.3.9.2. 15. Chlorophyll index

3.10.3 YIELD ATTRIBUTES

3.10.3.1 Cob length (cm)

Harvesting was done from a 1 m^2 area, and then randomly, 10 cobs were selected. Their length was measured with a scale, and their average was considered the mean value (Fig.3.10.3.1).

Figure. 3.10.3.1. Cob length (cm)

3.10.3.2 Cob number/plant

From the tagged plants' the cob number was counted in each plant with every treatment, and their average value was considered the mean value (Fig.3.10.3.2).

Figure.3.10.3.2. Cob number/plant

3.10.3.3 Cob placement height (cm)

The cob placement height was measured with a measuring scale from the base of the plant to the point where the cob was placed in the tagged plant from each treatment (Fig.3.10.3.3).

Figure.3.10.3.3. Cob placement height (cm)

3.10.3.4 Number of kernels row/cob

Ten randomly chosen cobs were used to count the number of kernel rows in each cob; the average of these counts was used to get the mean value.

3.10.3.5 Number of kernels/cobs

The mean value is calculated by averaging the total number of kernels counted in ten randomly chosen cobs from a 1 square meter sample (Fig. 3.10.3.5).

Figure.3.10.3.5. Number of kernels/cobs

3.10.3.6 100-grain weight (g)

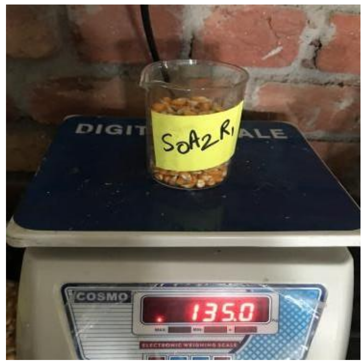
The average value of the 100 seeds used to determine the seed index was taken as the mean (Fig.3.10.3.6).

Figure. 3.10.3.6. 100-grain weight (g)

3.10.3.7 Kernels weight/cob (g)

The seed was separated from the cobs, and the cobs' weight was recorded in grams (Fig.3.10.3.7).

Figure.3.10.3.7. Kernels weight/cob (g)



3.10.3.8 Grain yield [ton/ha]

After the seeds were removed from the cobs, the harvested product was collected from each plot in 1 square meter, and the grain yield was recorded (Fig.3.10.3.8).

Figure.3.10.3.8 Grain yield ton/ha

3.10.3.9 Stover yield ton/ha

The straw yield was measured using a weighing machine from a 1 m^2 area after removing the cobs from the stalk (Fig. 3.10.3.9).

Figure.3.10.3.9. Stover yield ton/ha

3.10.3.10 Harvest index

The biological yield was calculated by weighing the harvested maize after it had dried in the field for three to four days. The Harvest index was then determined for each plot after the cobs were removed and grain yield was measured (Fig.3.10.3.10).

HI= Economical yield/Biological yield

Figure.3.10.3.10. Harvest index

3.11.4 QUALITY PARAMETER

Plant samples (grain and straw) were collected, washed, dried in the shade and in an oven at 65 ºC until a consistent weight was attained, and then ground for nutrient concertation and absorption. Plant analysis was performed using the processed plant samples. Nitrogen content in the processed plant samples should be determined using the micro-Kjeldahl's technique. Aliquots were prepared using the wet digestion (di-acid) technique to assess plant samples' P and K uptake concentration. Jackson (1973) explains how a spectrophotometer and flame photometer were used to analyse phosphorous and potassium using the vando-molybdate yellow colour technique.

3.11.4.1 Estimation of total nitrogen content in plant samples

Plant materials weighing 0.5 and 1 g (grain/straw) were poured into a 250 ml digestion tube. The digestive tube was filled with 20 ml of the sulphur-salicylic acid combination, turned so that any material stuck to the neck of the tube faced down, and left undisturbed for 2 hours. After giving it a good shake and letting it sit overnight, 2.5 grams of sodium sulfate were introduced via a long-stemmed funnel to the tube holding the content. The tubes on the block digester were preheated to 400 ºC, and a mixture of 4 g of catalyst and 3-4 grains of pumice were maintained. To prevent the loss of sulphuric acid and to keep the digestive process going until the liquid clears, a tiny glass funnel was left in the mouth of the tubes. The tubes were removed after 20 minutes of cooling in the block digester. After 2 hours of shaking, we put the boxes back on the block digester and let the contents digest. After being digested, the tube had no lingering particles. Once the digesting process was complete, the digest was cooled to room temperature before being diluted with distilled water to a final amount of 250 ml. A blank reagent sample and a reference plant specimen were always included in each set of samples digested. The 0.1 N sulphuric acid was used to titrate the digest until a purple tint developed.

3.11.4.2 Estimation of total phosphorous and potassium content in Plant samples

Dry plant materials are weighed between 0.5 and 1 g and transferred to the digesting tube. The digestive tube was refilled with a 10 ml di-acid (HNO_3+$HClO_4$) combination. The material was digested in a KEL plus digestion block at 150 degrees Celsius until the contents became colourless. The digested components were transferred to a 100 ml volumetric flask, and the volume was brought up to the appropriate level by adding distilled water. P and K uptake were calculated using the digested material. Molybdate vanadate phosphoric acid yellow colour technique (Jackson, 1973) was used to determine phosphorus concentrations. It was then mixed with 10 ml of the digested content reagent.

Distilled water was added to get the total amount to 50 ml. A spectrophotometer measured the luminance of the colours. The potassium concentration was calculated using a flame photometer (Chapman and Pratt 1961). Each set included one "control" and one "blank" plant specimen.

3.11.4.3 The crude fiber content in the leaf and seed of maize using the method introduced by Maynard A.J. (1970)

Principle

The native cellulose undergoes oxidative hydrolytic destruction, and lignin is significantly degraded during the acid and alkali treatment. The leftover material from the last filtering stage is weighed before being burned, cooled, and weighed again. Crude fiber content may be calculated by observing the weight loss.

Reagents

1. 0.255±0.005 N Standard H_2SO_4

2. 0.313± 0.005 N Standard NaOH

Procedure

Fat was removed by extracting two grammes of powdered dry sample with ether. The extracted sample was boiled in 200 ml of H_2SO_4 using bumping chips for 30 minutes. Acid was removed by filtering the residue through muslin fabric and washing it in hot water. NaOH was added to the residue and heated for 30 minutes. This went through another filter made of muslin fabric. Additional washes were performed using 25 ml of boiling H_2SO_4, 50 ml of water, and 25 ml of alcohol on the residue. The leftovers were poured onto a plate for ashing (W1) after they had been pre-weighed. Desiccators were used to dry the residue for two hours at 130 º C. There was a weigh-in. We're talking about W2. Ignite at 600 degrees Fahrenheit for 30 minutes. The measured total was W3. All measurements were made using gramme scales. The following formula was used to determine the quantity of crude fibre in the sample (Fig.3.11.4.3).

Weight of Loss sample = (W2-W1)- (W3-W1)

% Crude Fiber Content= Weight on Ignition Weight of Sample x 100

Figure.3.11.4.3. The crude fiber content in the leaf and seed of maize

3.11.4.4 Estimation of Energy by Bomb Colorimetric Method

- Maize seeds from different treatments were dried and then the fine powder was made with the help of a grinder.
- Weigh 1 g of fine powder sample and the pellet was made with the pellet press.
- And now the formed pellets were transferred to the sample cup.
- The fine wire was tied with an ignition coil along with thread and that thread should be in contact with the sample.
- After that the cap of the bomb reaction chamber was closed tightly and filled with oxygen at 20-25 atmospheric pressure.
- Now the bomb reaction chamber was placed inside the steel bomb colorimeter container and ignition wires were attached to the bomb reaction chamber.

- Thermometer and motorized stirrer were placed on its place inside the bomb colorimeter and switched on the machine and after some time it will give the reading in kcal/100 gm of the sample.
- Same procedure was followed for the calibration of the instrument but instead of sample pellets, a Benzoic acid pellet was used.

3.12.5 Economics analysis

The importance of economics in influencing the endorsement and adaption of farmers' practices cannot be emphasized. To get the highest possible net profit per acre, it is required to calculate the economics of various treatments.

3.12.5.1 Cost of cultivation

Recent market prices for fertilizers, manures, seed, irrigation, agrochemicals, labour costs, harvesting, and any other expenses associated with crop production are used to determine the total input cost for the different treatments.

3.12.5.2 Gross returns

Gross return is reflective of an investment's return before expenses or any deductions.

3.12.5.3 Net returns

After deducting the cultivation costs, the net profits were determined.

CHAPTER- IV

RESULTS AND DISCUSSION

This present research work was entitled "**Assessment of Quantitative and Qualitative Response of Hybrid Maize (*Zea mays* L.) under different Agrochemicals and Temporal Dynamics**" was conducted during the spring season in the year 2022 and 2023 as the field experiment in the Department of Agronomy, School of Agriculture, Lovely Professional University Phagwara. This study investigated the role of agrochemicals in different sowing dates of maize crops (PMH-10) at 30, 60, and 90 DAS. This field experiment evaluated morphologically and yield attributes parameters that lead toward the quantity of maize and the biochemical and seed quality parameters that enhance the quality of produced maize. The morphophysiological parameter of maize plant (PMH-10) at 30, 60, and 90 DAS was evaluated under the different sowing dates of maize along with the application of salicylic acid and sodium nitroprusside in all treatments as subfactor. Another part represents the biochemical estimation which plays an important role in maintaining the quality of produce and deals with the environmental stress mitigation due to changes in the sowing dates. The last part deals with yield attributes of maize and seed quality parameters which directly influence the quantity and quality of maize produced. All details of the experiment were mentioned both in the preceding and current chapters, an attempt has been made to depict as well as explanations regarding all the data which was recorded at different growing stages. The results of the research experiments trail are described below in the following headings.

4.1 Morphological Parameters

4.1.1 Days to 50 % Germination: The effect of different sowing dates and agrochemicals on days to 50 % germination was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was recorded at 20 DAS (Table 4.1.1.1, 4.1.1.2 and Figure 4.1.1.1a, 4.1.1.1b). In 2022 and 2023, there was a significant difference in days to 50 % germination in sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates and points of agrochemicals; it was estimated by comparing all the standards with control. Thus, the percentage pattern in days to 50% of germination was observed at 20 DAS. Therefore, in the case of different sowing dates, the percentage of days to 50% of germination was decreased in the case of early sowing (S0) by 27.28 % when compared with optimum sowing, but in the case of late sowing (SL), the days to 50 % of germination was increased by 18.34% as compared to optimum sowing (SE). The early sowing has taken a more significant number of days for germination as compared to the optimum and late sowing. The late sowing (SL) shows a better result by decreasing the days for germination as compared to optimum sowing (S0). It was recorded that in the case of agrochemicals, the application of sodium nitroprusside (A1) and combined application of salicylic acid and sodium nitroprusside showed better results by taking fewer days for the germination (A3) in the year 2022. The interaction effect of sowing dates and agrochemicals showed that late sowing with the application of salicylic acid and sodium nitroprusside (SLA3) decreased days to 50% germination 8.67% followed by SLA2<SLA1<S0A3<S0A1<S0A2<SEA1 as compared to the control. Similarly, in 2023, the percentage in days to 50% of germination was increased by 22.61% in early sowing (SE) compared to the optimum sowing (S0), and the days to 50% germination rate for late sowing (SL) decreased by 16.44 % compared to the optimum sowing. This result indicates that late sowing shows a better outcome for days to 50% germination. It was also recorded that in the case of applied agrochemicals, salicylic acid (A2) and sodium nitroprusside (A1) showed a similar result of 12.44 days to 50% germination as compared to control (A0). The interaction of different sowing dates and agrochemicals showed that the combined application of salicylic acid and sodium nitroprusside (SLA3) decreased the number of days for germination 10.00 followed by SLA3 <SLA1< S0A3< S0A2< S0A1<S0A0< SEA1<SEA3< SES2< SEA0. Within the complex realm of maize agriculture, the phenomenon of germination, which denotes the critical phase during which a seed undergoes a metamorphosis into a juvenile plant, is significantly impacted by the temporal aspect of sowing. This study examines the intricate nature of environmental stressors experienced by maize crops during germination when planted prematurely or belatedly within the recommended timeframe. Comprehending the scientific complexities associated with these stressors is imperative for elucidating the intricate relationship between germination and the dynamic fluctuations in environmental factors (Dahmardeh 2010; Saroj et al.,2018; Bhandari et al.,2018; Sharma and Saxena 2002; Prakash et al., 2021; Rai et al., 2018; Zhan Li et al., 2017; Meena et al., 2018; Amjadian et al., 2013). The germination phase of maize seeds is accompanied by environmental stressors when they are sown early. Late spring frosts present a considerable risk, subjecting the delicate germinating seeds to potentially harmful low temperatures. From a scientific perspective, this particular exposure can interfere with essential cellular processes crucial for germination, including water absorption and the activation of enzymes. Cold stress can impede the metabolic processes necessary for the seed to transition from a state of dormancy to one of active growth. Within the scientific domain, the presence of this interference can result in a delay in the germination process, a decrease in the overall strength and vitality of the plant, and, ultimately, a compromised ability to achieve optimal plant development. On the other hand, delayed sowing presents distinct environmental stressors during germination. The compressed temporal framework of the growing season exerts a significant influence on the seeds, compelling them to undergo rapid germination and establish the essential root and shoot structures that are imperative for subsequent growth. From a scientific perspective, it is plausible that the expedited germination process could lead to irregular growth patterns and diminished resilience in the nascent seedlings (Alam et al., 2018; Sanp and Singh 2018; Saroj et al., 2018; Singh et al., 2023; Backer et al., 2018). Late-sown maize seeds encounter the task of promptly adjusting to fluctuating environmental conditions, and the strain of accelerated germination can influence the overall efficacy of the subsequent plant life cycle. Investigating germination timing scientifically highlights the significance of identifying the optimal sowing window to enhance the environmental conditions during this pivotal stage. The suggested timing corresponds with optimal temperatures, soil moisture levels, and duration of daylight, creating an ideal setting for effective seed germination. From a scientific perspective, this synchronicity enables the prompt activation of enzymes, metabolic processes, and the development of a robust radicle, which plays a crucial role in anchoring the juvenile plant and facilitating the uptake of nutrients. The timing recommended for initiating the germination process is crucial in facilitating successful maize development by reducing the negative impact of environmental stressors that may hinder this critical stage (Kumar and Goh 1999; Souza et al., 2015; Vetter et al., 2023). To alleviate the effects of environmental stress on the germination process, a scientific methodology entails investigating the influence of growth regulators. Salicylic acid, which functions as a signalling molecule in the defence responses of plants, can be strategically administered to influence germination in unfavourable circumstances. From a scientific perspective, it has been observed that salicylic acid can stimulate the activation of stress response genes, thereby augmenting the seedlings' capacity to adapt to various environmental challenges effectively (Puglia et al., 2021; Buriro et al., 2015; Dias et al., 2022; Fadiji et al., 2022; Gopalakrishnan and Ghosh 2022; Jin-gui et al., 2023; Bolan et al., 2011; Kumar and Singh 2019). Implementing this strategic approach can potentially enhance the germination process, specifically in the case of early-sown maize susceptible to the adverse effects of late frosts. Moreover, using sodium nitroprusside as a nitric oxide donor presents a scientific intervention to augment germination. When sodium nitroprusside is applied with precision, it plays a crucial role in facilitating essential physiological processes that occur during the germination of plants. Specifically, it promotes cell division and elongation processes, which are vital for the growth and development of plant cells. This phenomenon has a scientific basis and plays a significant role in fostering the growth and resilience of seedlings (Van Staden 2011; Zhen et al., 2006; Gupta et al., 2022; Zema et al., 2018; Gunasekera and Ratnasekera 2023). It is particularly advantageous for late-sown maize seeds that face the challenge of rapidly establishing themselves within a condensed cultivation period. In summary, the scientific investigation of environmental pressures during the germination process of maize provides a comprehensive comprehension of the intricate interplay between timing and ideal circumstances. The cultivation of maize planted early is hindered by the adverse impact of late frosts on the complex germination process, whereas maize grown later encounters the challenge of coping with accelerated growth. Based on scientific principles, the timing for sowing is crucial in creating an optimal environment for adequate germination. Incorporating growth regulators, such as salicylic acid and sodium nitroprusside, into the scientific methodology provides a systematic way to improve germinating maize seeds' robustness. The investigation into germination timing and environmental stressors in maize fields offers valuable insights into the fundamental mechanisms that influence the growth and productivity of maize crops (YU et al., 2016; Jangir et al., 2021; Pui Kin and Yang 2023; Herrmann et al., 2017; Wang and Stewart 2013; Moulick et al., 2018; de Paula do Nascimento et al., 2023).

Table 4.1.1.1 Effect of treatments on days to 50 % germination of maize at 20 DAS during spring season 2022 and 2023

Treatments	Days to 50 % germination 2022	Days to 50 % germination 2023
Sowing Date		
SE -Early sowing	13.25	14.91
S0 -Optimum sowing	10.41	12.16
SL -Late sowing	8.50	10.16
Agrochemical		
A0- Control	10.77	12.44
A1-Sodium nitroprusside (250 µM/L)	10.77	12.55
A2-Salicylic acid (150mg/L)	11.00	12.66
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	10.33	12.00
Alpha at 0.05		
CV (Sowing date and agrochemical)	5.82	4.71
CV (Sowing)	4.53	4.65
CD (Agrochemical)	0.55	0.65
CD (Sowing)	0.61	0.57

Table 4.1.1.2 The interaction effect of different treatments on days to 50 % germination of maize at 20 DAS during spring season 2022 and 2023

Treatments	Days to 50 % germination 2022	Days to 50 % germination 2023
SEA0	$13.67^{a}\pm0.58$	$15.33^{a}\pm1.15$
SEA1	$12.67^{a}\pm0.58$	$14.33^{a}\pm1.15$
SEA2	$13.67^{a}\pm0.58$	$15.33^{a}\pm0.58$
SEA3	$13.00^{a}\pm1.00$	$14.67^{a}\pm1.53$
S0A0	$11.00^{bb}\pm1.00$	$12.67^{b}\pm1.53$
S0A1	$10.33^{bc}\pm0.58$	$12.33^{bc}\pm0.58$
S0A2	$10.67^{bcd}\pm0.58$	$12.33^{bc}\pm1.15$
S0A3	$9.67^{cde}\pm0.58$	$11.33^{cd}\pm1.15$
SLA0	$7.67^{g}\pm0.58$	$9.33^{f}\pm0.58$
SLA1	$9.33^{def}\pm0.58$	$11.00^{de}\pm1.00$
SLA2	$8.67^{efg}\pm0.58$	$10.33^{def}\pm1.15$
SLA3	$8.33^{fg}\pm0.58$	$10.00^{ef}\pm1.00$
CV	5.82	4.71
CD	1.06	1.07

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.1.1.1a. Effect of sowing dates and agrochemicals treatments on days to 50 % germination of maize at 20 DAS during spring season 2022

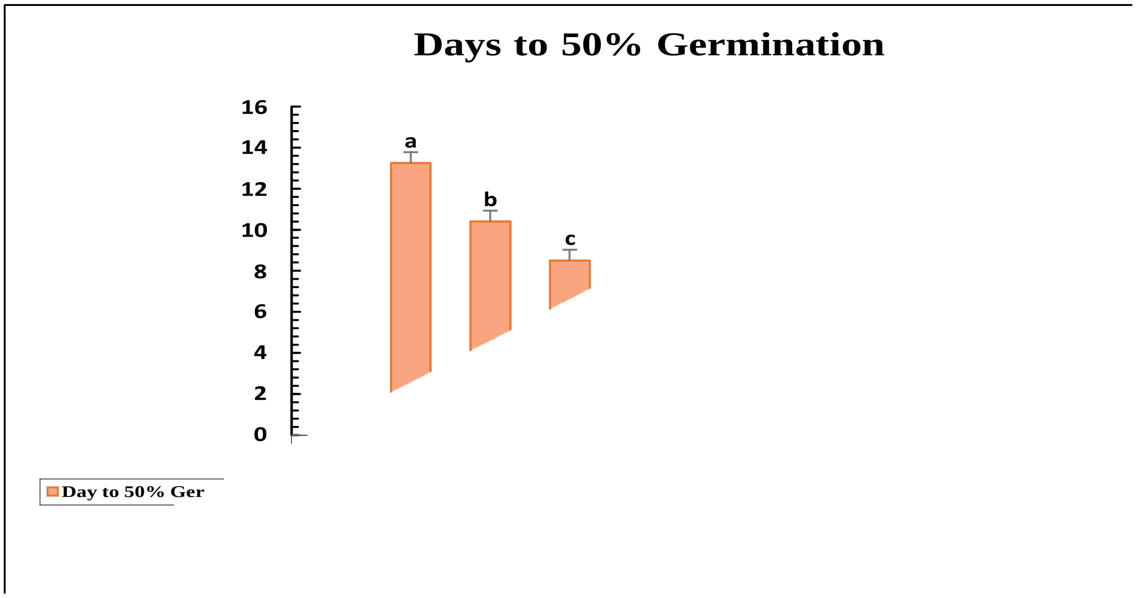
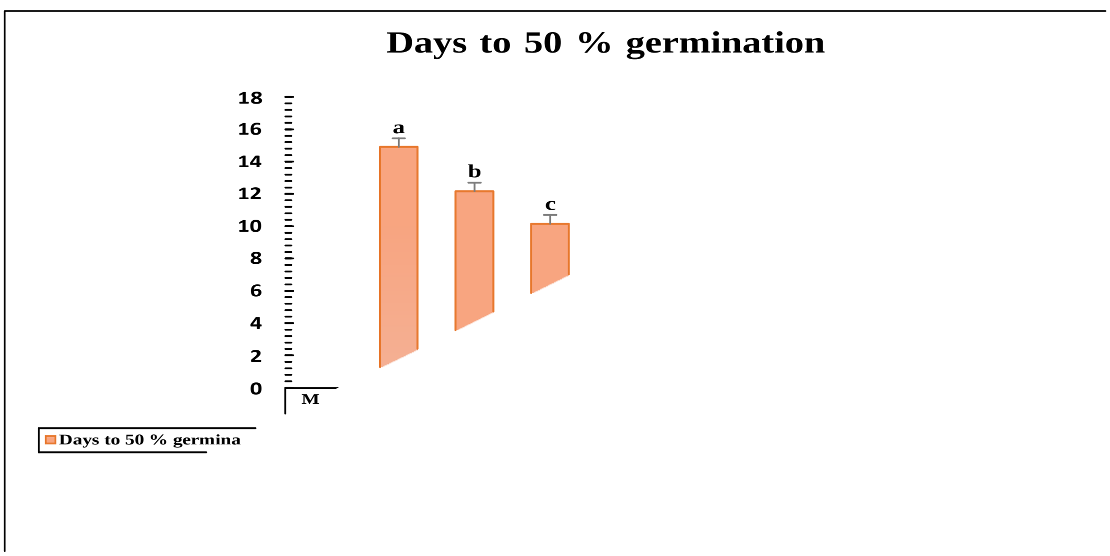


Figure 4.1.1.2b. Effect of sowing dates and agrochemicals treatments on days to 50 % germination of maize at 20 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.1.2 Plant Height (cm): The effect of different sowing dates and agrochemicals on Plant height (cm) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS shown in (Table 4.1.2.1, 4.1.2.2 and Figure 4.1.2.1a, 4.1.2.2b). In 2022 and 2023, there was a significant difference in the percentage of plant height in sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standard with control. Thus, the percentage pattern in plant height was observed at 30, 60, and 90 DAS. Therefore, in the case of different sowing dates, the early sowing (SE) decreased the percentage of plant height by 86.02%, and late sowing (SL) also reduced the percentage of plant height by 9.08% as compared to the optimum sowing (S0) at 30 DAS. At 60 DAS, early sowing (SE) and late sowing (SL) increased the percentage of plant height by 3.55% and 9.70%, respectively, when compared with the optimum sowing (S0) as control. Similarly, at 90 DAS, the percentage of plant height was decreased in the case of early sowing (SE) by 3.20% and increased in the case of late sowing (SL) by 2.66%, respectively, when compared to the optimum sowing (S0). The percentage of plant height in agrochemicals showed that sodium nitroprusside (A1) decreased by 1.60 % and 13.82 % in (A3) compared to the control. Still, the application of salicylic acid (A2) increased the percentage of plant height by 13.82 compared to the control at 30 DAS. At 60 DAS, the percentage of plant height was increased by 3.82 %, 2.92%, and 3.27 in A1, A2, and A3, respectively, compared to the control. Similarly, at 90 DAS, the application of sodium nitroprusside and salicylic acid (A3) was able to increase the percentage of plant height by 9.04%, followed by sodium nitroprusside (A1) and salicylic acid (A2) by 6.76% and 1.92% respectively. The interaction effect of sowing dates and agrochemicals showed that late sowing with the application of salicylic acid showed a better result by increasing the plant height by 39.98 9 (cm) followed by S0A0> S0A2> S0A1>SLA1>S0A3 SLA0 >SLA3 >SEA3 >SEA2 >SEA1>SEA0 respectively. In the year 2023, the percentage of plant height decreased in early sowing (SE) by 82.42% and late sowing (SL) by 8.69%, respectively, when compared with the optimum sowing (S0). The percentage of applied agrochemicals showed the highest in A2 at 12.95% at 30 DAS compared to control A0. At 60 DAS, the highest rate was found in A1, i.e. 3.77%, compared to A0, followed by A3 A2, and the percentage values were 3.32% and 3.07%, respectively. The interaction effect of sowing dates and agrochemicals showed the highest percentage in SLA2 followed by S0A0, S0A2, S0A1, SLA1, S0A3, SLA0, SLA3, and percentage values were 41.48%, 38.12%,35.37%,33.46%,33.18%,32.98%,29.78%, and 23.32% respectively at 30 DAS. The lowest plant height was found in SEA0, i.e. 5.71. AT 60 DAS, the highest was found in SLA1, the lowest percentage was in S0A1, and the values were 98.80 cm and 79.63 cm, respectively. Similarly, at 90 DAS, the highest plant height was found in S0A0 and the lowest plant height was found in SLA3 at 167.90 cm and 129.90, respectively. Within the domain of agriculture, the investigation into the influence of sowing timing on environmental stressors presents an intriguing scientific exploration. The cultivation of *Zea mays*, commonly known as maize plants, can present notable difficulties when exposed to early sowing due to their vulnerability to late spring frosts. The occurrence of frost presents a significant peril to the vulnerable seedlings, potentially impeding their growth by causing harm to their cellular structure and disrupting the essential metabolic processes required for their initial stages of development. The physiological responses of plants, including their height and vitality, can be significantly impacted by the stress caused by premature exposure to cold temperatures. On the contrary, sowing seeds at a later stage introduces a distinct array of environmental stressors, predominantly arising from the condensed duration of the growth period (Iqbal et al., 2018; Yao et al., 2017; Kutman 2023; Ventura et al., 2010; Srinivasa and Naidu 2021). Late-sown plants encounter the obstacle of heightened growth demands as they endeavour to achieve their maximum height before the onset of unfavourable climatic conditions. The imposition of this temporal limitation substantially impedes their capacity to carry out essential developmental procedures effectively. The stress caused by a shortened growing season may affect the plant's developmental pathways, resulting in decreased height and impaired physiological functions. The environmental stress experienced by plants sown at different times, both early and late, is contrasted with the backdrop of the recommended sowing timing. This suggested timing is determined through scientific calculations to maximize growth conditions. When seeds are sown within the designated timeframe, the plants experience advantageous conditions resulting from a favourable combination of environmental elements, such as temperature, moisture, and daylight. Synchronicity creates a good setting that promotes substantial growth, thereby reducing the adverse effects of stressors that may hinder the plants' progress. Plants sown early face the challenge of being vulnerable to frost and the potential interference with their optimal growth processes. The impact of colder temperatures on crucial cellular processes, such as photosynthesis and nutrient absorption, ultimately affects the growth of plants (Etesami and Glick 2020; Galindo et al., 2022; Rafiee et al., 2016). On the other hand, seed sown later in the season encounters the obstacle of an accelerated growth cycle, resulting in an acceleration of metabolic processes that could hinder the plants' capacity to attain their predetermined height potential. These scientific nuances highlight the complex interactions among timing, environmental stress, and physiological responses of plants. Applying growth regulators, such as salicylic acid and sodium nitroprusside, is crucial in mitigating environmental stress. Salicylic acid, an essential signalling molecule involved in plant defence mechanisms, has demonstrated advantageous effects when applied to early-sown plants exposed to the risk of late frosts. From a scientific perspective, salicylic acid is a stimulator of stress response genes, initiating pathways that augment the plants' capacity to endure unfavourable circumstances. Salicylic acid plays a role in the modulation of biochemical processes, leading to cell elongation and structural reinforcement (Kaul and Passi 2023; Yaojun Zhang et al., 2019; Blackwell et al., 2018; Shi et al., 2019; Salam et al., 2022; Kaczynski et al., 2016; Costa et al., 2022). This biochemical mechanism helps alleviate the adverse effects of frost-induced stress on early-sown plants, promoting optimal height growth. Using sodium nitroprusside as a nitric oxide donor introduces an additional dimension to the scientific approach towards stress alleviation. In the context of delayed planting of maize, which is subject to time limitations that exacerbate stress, sodium nitroprusside has been identified as a growth regulator that affects various cellular processes. From a scientific perspective, it has been observed that the application of this substance facilitates the process of cell division and elongation. Consequently, it enhances plants' growth potential later in the season, enabling them to overcome the limitations imposed by a shortened growing period and attain a desirable height. The intricate utilization of these growth regulators demonstrates their capacity to regulate the physiological reactions of plants when confronted with environmental stressors resulting from deviation from the suggested sowing schedule (Watson et al., 2017; Yajie Zhang and Niu 2016; Vivek et al., 2019; Wang et al., 2023; Goyal et al., 2019; Wang et al., 2018). The scientific discourse about the environmental stress experienced by plants due to early and late sowing is characterized by a multifaceted interaction involving cellular processes, genetic manifestation, and growth control mechanisms. The necessity for accurate timing in agricultural practices is emphasized by the vulnerability of early-sown seed to frost-induced stress and the difficulties associated with promoting rapid growth in late-sown counterparts. The timing of sowing, based on scientific principles, is crucial in creating ideal growth conditions, reducing stress, and promoting the healthy development of plants. Incorporating growth regulators introduces complexity to this scientific investigation, providing deliberate interventions to strengthen the plants against environmental adversities and augment their ability to withstand stress. Investigating timing, stress responses, and growth regulation in maize fields provides a scholarly exploration of the complex interaction between maize plants and their surrounding environment (Cui et al., 2012; Dwivedi et al., 2013; Cordovil et al., 2020).

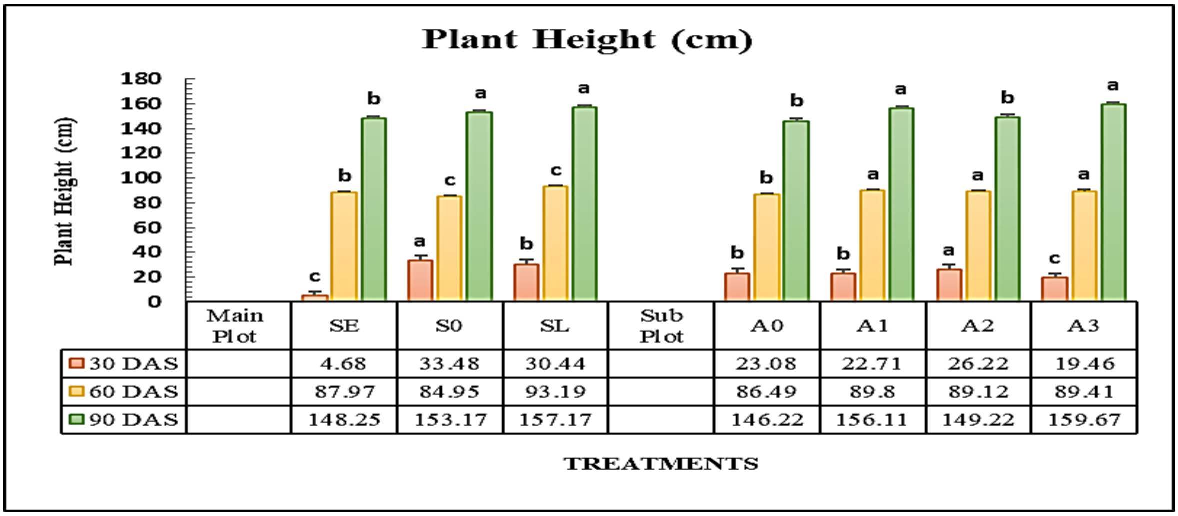
Table 4.1.2.1 Effect of treatments on plant height (cm) of maize at 30, 60, and 90 DAS during the spring season 2022 and 2023

Treatments	**Plant height (cm)-2022**			**Plant height (cm)-2023**		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	4.68	87.97	148.25	6.15	89.27	153.54
S0 -Optimum sowing	33.48	84.95	153.17	34.98	86.26	159.28
SL -Late sowing	30.44	93.19	157.17	31.94	94.49	150.55
(Agrochemicals)						
A0- Control	23.08	86.49	146.22	24.54	87.79	158.01
A1-Sodium nitroprusside (250 µM/L)	22.71	89.80	156.11	24.21	91.10	151.40
A2-Salicylic acid (150mg/L)	26.22	89.12	149.22	27.72	90.43	161.54
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	19.46	89.41	159.67	20.96	90.71	146.88
CV (Sowing)	3.71	1.23	2.62	3.36	1.22	3.48
CV (Sowing date and agrochemical)	4.29	1.39	3.62	4.05	1.37	3.45
CD (Sowing)	0.96	1.24	4.53	0.92	1.24	6.08
CD (Agrochemicals)	0.97	1.21	5.48	0.97	1.21	5.27

Table 4.1.2.2 The interaction effect of treatments on plant height (cm) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

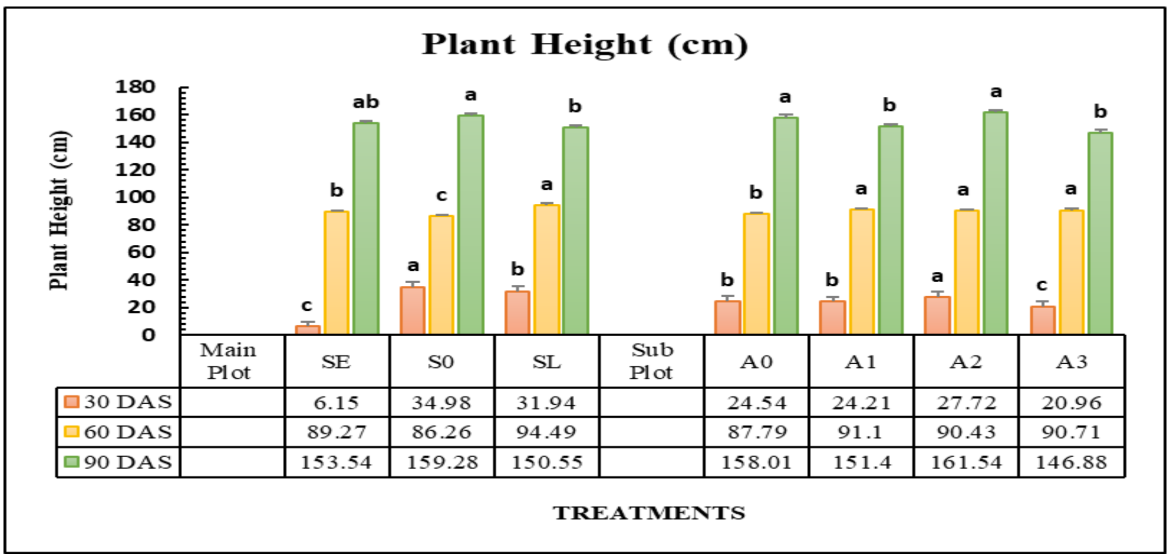
Treatments	Plant height (cm)-2022			Plant height (cm)-2023		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
SEA0	4.34 ^{g}±0.07	80.21^{f} ±1.07	146.33^{g} ±5.59	5.72 ^{g} ± 0.15	81.51 ^{f} ±1.07	148.30 ^{efg} ± 5.53
SEA1	4.48 ^{g}±0.22	93.57^{b}±0.43	150.67^{ef} ±8.50	5.98 ^{g} ± 0.22	94.87 ^{b} ± 0.43	152.73 ^{def} ± 8.51
SEA2	4.83 ^{g}±0.58	95.02^{b} ±1.27	164.33^{de} ±6.66	6.33 ^{g} ± 0.58	96.32 ^{b} ± 1.27	166.23 ^{ab} ± 6.94
SEA3	5.09^{g}±0.27	83.07^{e} ±0.90	145.00^{ab} ±5.29	6.59 ^{g} ± 0.27	84.37 ^{e} ± 0.90	146.90 ^{fg} ± 5.62
S0A0	36.62^{b} ±1.02	84.77^{de} ±0.80	166.00^{ef} ±5.00	38.12 ^{b} ± 1.02	86.07 ^{de} ± 0.80	167.90 ^{bcde} ± 4.76
S0A1	31.97^{d} ±1.03	78.33^{f} ±0.46	139.67^{a} ±2.52	33.47 ^{d} ± 1.03	79.63 ^{f} ±0.46	141.57 ^{a} ±2.18
S0A2	33.87^{c} ±1.41	85.80^{d} ±0.40	162.00^{fg} ±5.29	35.37 ^{c} ± 1.41	87.10 ^{d} ± 0.40	163.83 ^{g} ±5.11
S0A3	31.48^{d} ±0.59	90.93^{c} ±0.12	162.00^{abc} ±3.00	32.98 ^{d} ± 0.59	92.23 ^{c} ±0.12	163.83 ^{abc} ±2.75
SLA0	28.29^{e} ±1.25	94.50^{b}±3.18	156.00^{abc} ±5.00	29.79 ^{e} ± 1.25	95.80 ^{b} ± 3.18	157.83 ^{abc} ±5.25
SLA1	31.69 ^{d}±0.55	97.50^{a} ±0.44	158.00^{bcd} ±4.58	33.19 ^{d} ± 0.55	98.80 ^{a} ± 0.44	159.90 ^{bcde} ± 4.55
SLA2	39.98^{a}±1.84	86.56^{d} ±0.51	152.67^{abcd} ±5.03	41.48 ^{a} ± 1.84	87.86 ^{d} ±0.51	154.57 ^{abcd} ± 5.06
SLA3	21.83^{f} ±0.76	94.22^{b} ±1.17	128.00^{cde} ±3.61	23.33 ^{f} ± 0.76	95.52 ^{b} ±1.17	129.90 ^{cdef} ± 3.57
CV	4.29	1.39	3.62	4.05	1.37	3.45
CD	1.73	2.19	9.34	1.72	2.19	9.89

Figure 4.1.2.1a. Effect of sowing dates and agrochemicals treatments on plant height (cm) of maize at 30, 60, and 90 DAS during spring season 2022



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		4.68	33.48	30.44		23.08	22.71	26.22	19.46
60 DAS		87.97	84.95	93.19		86.49	89.8	89.12	89.41
90 DAS		148.25	153.17	157.17		146.22	156.11	149.22	159.67

Figure 4.1.2.2b. Effect of sowing dates and agrochemicals treatments on plant height (cm) of maize at 30, 60, and 90 DAS during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		6.15	34.98	31.94		24.54	24.21	27.72	20.96
60 DAS		89.27	86.26	94.49		87.79	91.1	90.43	90.71
90 DAS		153.54	159.28	150.55		158.01	151.4	161.54	146.88

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.1.3 Number of Leaves/Plant: The impact of sowing dates and agrochemicals on the Number of leaves was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS shown in (Table 4.1.3.1, 4.1.3.2 and Figure 4.1.3.1a,4.1.3.2b). In 2022 and 2023, there was a significant difference in the percentage of the number of leaves sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals; it was calculated by comparing all the mean with control. Thus, the percentage pattern in the number of leaves was observed at 30, 60, and 90 DAS. It was recorded that in the case of early sowing (SE) and late sowing (SL), the percentage was decreased by 2.60% and 2.60% as compared to the optimum sowing (S0) at 30 DAS. At 60 DAS, the percentage decreased in early sowing (SE) by 9.46% as compared to the optimum sowing (S0) and late sowing (SL). Similarly, the percentage of the number of leaves was decreased in early sowing (SE) and late sowing (SL) by 3.92% and 1.04%, respectively, when compared to the optimum sowing (S0) at 90 DAS. The application of agrochemicals also showed better results by increasing the number of leaves; at 30 DAS, the A1 decreased the percentage by 7.67% as the A2 and A3 increased the percentage of the number of leaves per plant by 7.945 and 3.41%, respectively, as compared to the control A0. At 60 DAS, agrochemicals (A3) combined application showed a better result by increasing the percentage by 1.77 compared to the A1 and A2. Similarly, at 90 DAS, A2 showed a better result by increasing the percentage by 1.92, followed by A1 and A2, respectively. In the year 2023, late sowing (SL) increased the percentage by 2.92% as compared to the early sowing (SE) and optimum sowing (S0) at 30 DAS. At 60 DAS the early sowing decreased the percentage by 9.34% compared to the optimum sowing (S0). But in the case of 90 DAS, the percentage of the number of leaves increased in early sowing (SE) and late sowing (SL) by 9.30% and 11.62%, respectively, when compared to the optimum sowing (S0). It was also recorded that salicylic acid A2 shows better results among the applied agrochemicals by increasing the percentage by 18.66%, followed by the A3, i.e.,1.59% at 30 DAS. Similarly, at 60 DAS, the A2 has the highest percentage of leaves number, i.e. 3.19%, followed by the A3 by 1.59%, and in the case of 90 DAS, the A2 shows a better result by increasing the percentage by 5.97%, followed by the A1 and A2 respectively. Within the complex domain of maize crop cultivation, the quantity of leaves present on each plant is a discernible indicator of the plant's holistic well-being and developmental progress. This study delves into the intricate dynamics of environmental stressors experienced by crops regarding leaf count when planted either too early or too late compared to the recommended planting timeframe. Comprehending the scientific complexities associated with leaf development is imperative to elucidate the intricate relationship between environmental factors, the timing of germination, and the subsequent phases of vegetative growth (Melelli et al., 2022; Guha et al., 2021; Niaounakis and Halvadakis 2006; Escobar et al., 2020). If seeds are planted prematurely, the resulting seedlings become susceptible to various environmental stressors that can substantially affect leaf production. Late spring frosts present a significant risk, as they have the potential to cause harm to delicate young shoots and impede the plant's ability to commence and maintain leaf development. From a scientific perspective, it has been observed that being exposed to cold temperatures can hinder the cellular processes that are crucial for the development of leaves, including photosynthesis and the absorption of nutrients. The impact of cold stress on early-sown plants is a significant determinant in restricting leaf count, thereby influencing their overall vitality and capacity for vigorous vegetative development. On the other hand, sowing plants later than the optimal time introduces a unique array of environmental stressors that impact the plants' leaf count. The condensed duration of the growing season imposes significant stress on crops that are sown later, necessitating an accelerated rate of leaf development. From a scientific perspective, the condensed period could decrease leaf count as the plants expedite their progression through the vegetative stage to allocate resources towards reproductive activities. The plants' capacity to maximize leaf growth and achieve an optimal leaf canopy for efficient photosynthesis is adversely affected by the tangible pressure imposed by time constraints. The timing of sowing is a crucial factor in the scientific investigation of leaf development, as it plays a significant role in creating favourable conditions for maize growth. The timing recommended is by optimal environmental conditions, such as temperature, soil moisture, and daylight duration, which all play a role in facilitating the efficient growth of leaves. From a scientific perspective, the synchronization of maize plants allows for the development of a strong leaf canopy, which is crucial for efficient sunlight absorption and the facilitation of photosynthesis(Van Alfen 2014; Sarker et al., 2022; Pedraza et al., 2020;

Morel et al., 2021; Sun et al., 2023; Yuling Guo et al., 2023; Sun et al., 2023; Yibo Li and Tao 2023; Yang et al., 2023; Köksal and Taner 2023; Maucieri and Borin 2023). The suggested timing establishes the conditions for achieving an optimal leaf count, which is critical in determining the plant's ability to generate energy and maintain its overall well-being. To address the adverse effects of environmental stress on leaf development, a scholarly approach entails the examination of growth regulators. Salicylic acid, renowned for its involvement in plant defence mechanisms, can be deliberately administered to modulate leaf development in unfavourable circumstances. From a scientific standpoint, salicylic acid's activation of stress response genes has been observed to augment the plant's capacity to endure various environmental adversities, thereby potentially facilitating the growth of a robust leaf canopy. This strategic approach is especially pertinent in the context of early-planted maize, as it provides a scientific method to enhance the resilience of the plants against the potential detrimental effects of late frosts on leaf growth. In addition, using sodium nitroprusside as a nitric oxide donor offers a scientific intervention to enhance leaf growth. When used carefully and deliberately, sodium nitroprusside can impact vital physiological mechanisms, such as cell division and elongation, which play a fundamental role in the development of leaves. From a scientific perspective, this application significantly promotes the development of a strong leaf canopy (Liu et al., 2023; Zhao et al., 2023; Yaqiu Zhu et al., 2023; Fernández-Ortega et al., 2023; Zhu et al., 2023). This is particularly advantageous for late-sown crops, as it helps accelerate the plant's vegetative growth despite the limitations imposed by a shortened growing season. The scientific investigation of environmental pressures on leaf count in crop plants provides insights into the intricate interplay among timing, growth circumstances, and vegetative growth. A crop that is sown early encounters the obstacle of late frosts that hinder the development of its leaves, whereas plants that are planted late experience the difficulty of a condensed growing season, which poses additional stress. The timing of sowing, which is based on scientific principles, plays a crucial role in creating the most favorable conditions for leaf development.

Table 4.1.3.1 Effect of treatments on number of leaves of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Number of leaves-2022			Number of leaves-2023		
At different Interval	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
(Sowing Date)						
SE -Early sowing	3.00	6.41	11.53	3.08	6.50	11.75
S0 -Optimum sowing	3.08	7.08	12.00	3.08	7.17	10.75
SL -Late sowing	3.00	7.08	10.75	3.17	7.17	12.00
(Agrochemicals)						
A0- Control	3.00	6.88	11.33	3.00	6.89	11.22
A1-Sodium nitroprusside (250 µM/L)	2.77	6.77	11.44	2.78	6.78	11.44
A2-Salicylic acid (150mg/L)	3.22	6.77	11.55	3.56	7.11	11.89
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	3.11	7.00	11.44	3.11	7.00	11.44
CV (Sowing)	17.41	10.16	12.94	21.43	6.35	11.77
CV (Sowing date and agrochemical)	23.57	11.39	8.02	20.75	10.46	7.71
CD (Sowing)	0.59	0.79	14.31	0.75	0.49	1.53
CD (Agrochemicals)	0.70	0.77	13.14	0.63	0.71	0.87

Table 4.1.3.2 Interaction effect of treatments on number of leaves of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Number of leaves-2022			Number of leaves-2023		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
SEA0	3.00^{abc} ±0.00	6.67^{ab}±1.53	11.33^{a} ±1.15	3.00^{abc} ±0.58	6.00^{c} ±1.00	11.33^{ab} ±1.52
SEA1	3.00^{abc}±1.00	6.00^{b}±1.00	11.33^{a}±1.53	3.33^{abc} ±0.58	7.00^{abc} ±1.00	12.00^{ab} ±2.00
SEA2	3.00^{abc} ±0.00	6.67^{ab}±1.53	11.33^{a} ±1.15	3.33^{abc} ±1.15	7.00^{abc} ±1.00	12.00^{ab} ±0.57
SEA3	2.67^{bc}±1.15	6.00^{b}±0.00	11.67^{a} ±1.15	2.66^{bc} ±0.58	6.00^{c} ±0.57	11.67^{ab} ±1.15
S0A0	2.67^{bc}±0.58	7.00^{ab}±0.00	12.33^{a}±1.53	2.66^{bc} ±0.58	7.00^{abc} ±0.577	12.33±1.52a
S0A1	2.67^{bc}±0.58	7.00^{ab}±1.00	11.33^{a} ±0.58	2.66^{bc} ±0.58	7.00^{abc} ±1.00	11.33^{ab} ±0.57
S0A2	4.00^{a}±0.00	6.67^{ab}±0.58	12.33^{a} ±0.58	4.00^{a} ±1.00	7.00^{abc} ±1.00	12.33^{a} ±0.57
S0A3	3.00^{abc}±1.00	7.67^{a}±0.58	12.00^{a}±1.73	3.00^{abc} ±0.58	7.66^{a} ±0.57	12.00^{ab} ±0.57
SLA0	3.33^{abc}±0.58	7.67^{a}±0.58	10.33^{a} ±0.58	3.33^{abc} ±0.58	7.66^{a} ±0.57	10.00^{b} ±1.15
SLA1	2.33^{c}±0.58	6.33^{ab}±1.15	11.00^{a} ±0.00	2.33^{c} ±0.58	6.33^{bc} ±1.15	11.00^{ab} ±0.57
SLA2	2.67^{bc}±0.58	7.00^{ab}±1.73	11.00^{a} ±0.00	3.33^{abc} ±0.58	7.33^{ab} ±1.15	11.33^{ab} ±0.57
SLA3	3.67^{ab}±0.58	7.33^{ab}±1.15	10.67^{a} ±0.58	3.66^{ab} ±0.58	7.73^{ab} ±1.15	10.67^{ab} ±0.57
CV	23.57	11.39	8.02	20.75	10.46	7.71
CD	23.57	11.39	19.88	1.21	1.18	2.00

Figure 4.1.3.1a. Effect of sowing dates and agrochemicals treatments on number of leaves of maize at 30, 60, and 90 DAS during spring season 2022

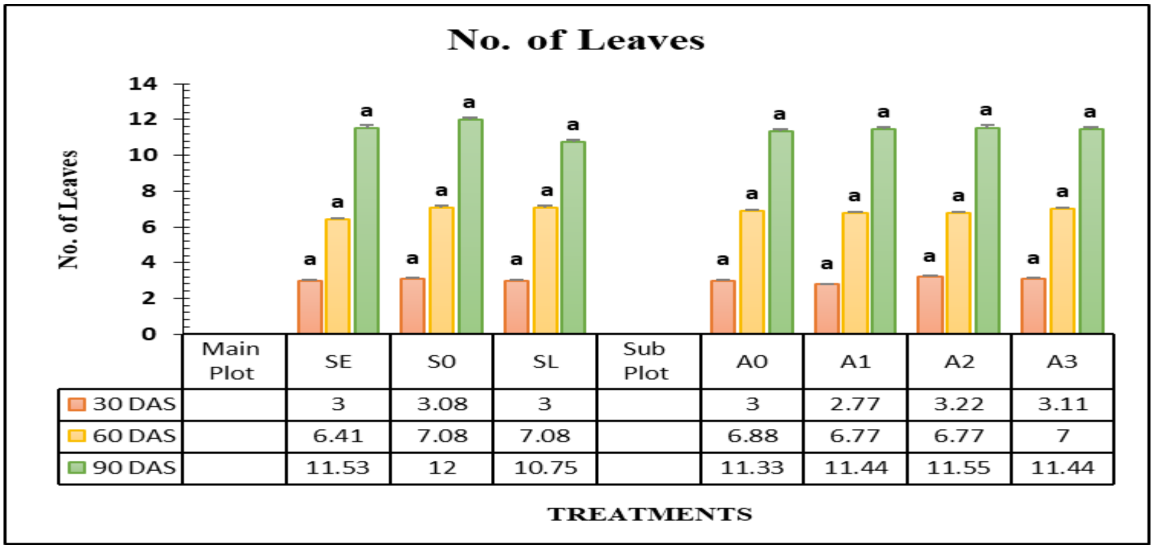
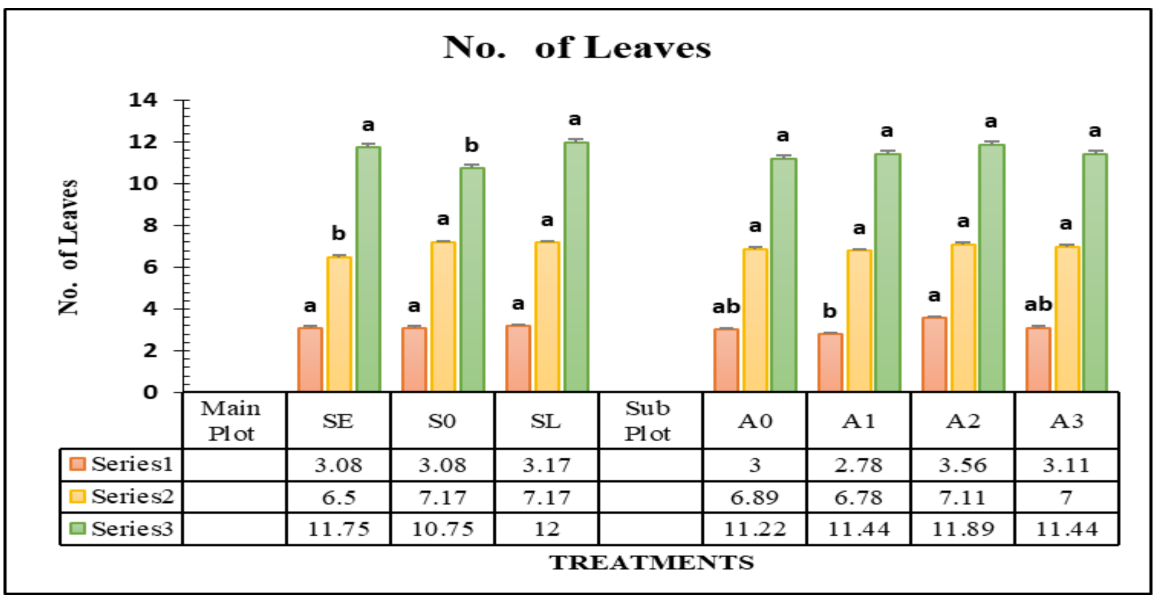


Figure 4.1.3.2b. Effect of sowing dates and agrochemicals treatments on number of leaves of maize at 30, 60, and 90 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.1.4 Internodal Length (cm): The impact of sowing dates and agrochemicals on Internodal Length (cm) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS (Table 4.1.4.1, 4.1.4.2, and Figure 4.1.4.1a,4.1.4.2b). In 2022 and 2023, there was a significant difference in the percentage of Internodal Length (cm) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals it was calculated by comparing all the mean with control. Thus, the percentage pattern in the Internodal Length (cm) was observed at different intervals 30, 60, and 90 DAS. It was recorded that in 2022, the different sowing dates, the early sowing (SE) and late sowing (SL), decreased the percentage by 7.27% and 3.49%, respectively, as compared to the optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing (SE) was able to increase the percentage by 3.08%, and late sowing (SL) decreased the rate by 9.47%, respectively, when compared with optimum sowing (S0). In the case of 90 DAS, the same trends were observed. SE shows better results by increasing the percentage by 8.92%, and SL decreased the rate by 10.3% compared to the S0. In the case of the agrochemicals, the application of sodium nitroprusside showed a better result by increasing the rate by 0.41% compared to the control A0 at 30 DAS. Similarly, at 60 DAS, there is no significant increase in the rate of applied agrochemicals. But at 90 DAS, salicylic acid (A2) application increased the rate by 1.73% compared to the control (A0). In the year 2023, it was recorded that early sowing (SE) and late sowing (SL) decreased the percentage by 68.51% and 32.87%, respectively, when compared to the optimum sowing (S0) at 30 DAS. At 60 DAS, early sowing (SE) shows a better result by increasing the percentage by 3.09% compared to the optimum sowing (S0). The 90 DAS SE increased the rate by 7.74% compared to the optimum sowing (S0). It was observed that among applied agrochemicals, the application of sodium nitroprusside (A1) increased the percentage by 0.77% compared to the control at 30 DAS. In the case of 60 DAS, the combined application shows a better result by increasing the rate by 0.54% compared to the control (A0). At 90 DAS, salicylic acid (A2) application increased the rate by 5.02% compared to the other applied agrochemicals. In the complex realm of agricultural practices, the internodal length of a plant emerges as a crucial determinant of its reaction to various environmental stress factors. Compared to the recommended planting schedule, this study examines the intricate dynamics of internodal size in crops under untimely sowing, either prematurely or delayed (Wen Ren et al., 2023; FAN et al., 2023; Dzvene et al., 2023). Gaining a comprehensive comprehension of the scientific complexities associated with internodal elongation is of utmost importance to decipher the intricate interactions among environmental factors, the timing of germination, and the subsequent phases of vegetative growth in this essential agricultural crop. Planting seeds before their optimal time can render emerging seedlings vulnerable to various environmental stressors, which substantially affect the length between nodes. Late spring frosts present a significant risk, potentially impeding the elongation of internodes and restricting the overall height capacity of the plants. From a scientific perspective, it has been observed that being exposed to cold temperatures can interfere with crucial cellular processes that are necessary for the growth of internodes. These processes include the elongation and expansion of cells. The effects of cold stress are observed in the reduced internodal length of plants sown early, subsequently impacting their overall growth and development. On the other hand, sowing crops later than usual introduces specific environmental stressors that impact the length of internodes. The condensed duration of the growing season imposes considerable stress on plants, compelling them to accelerate the elongation of internodes. From a scientific standpoint, the shortened duration may decrease internodal length as the plants expedite their growth during the vegetative phase to allocate resources towards reproductive processes. The ability of maize plants to effectively regulate internodal growth and achieve the desired spacing between nodes is hindered by the tangible limitations imposed by time constraints. The intricate scientific aspects of this process highlight the importance of maintaining a delicate equilibrium in developing internodal length, particularly when faced with different environmental stressors that may arise from deviating from the suggested timing for sowing. Determining the appropriate timing for sowing is of utmost importance in the scientific examination of internodal length, as it establishes the most favourable conditions for the growth of crops. The synchronization coincides with advantageous ecological factors, such as temperature, soil moisture, and duration of daylight, all of which promote efficient elongation between nodes (Su et al., 2023; Junming Liu et al., 2023; Wang et al., 2023). From a scientific standpoint, this synchronization facilitates the timely initiation of cellular processes, such as the elongation of cells in the internodes. The suggested timing establishes the conditions necessary for attaining an ideal internodal length, a crucial factor in determining the plant's structural stability and overall development. To alleviate the effects of environmental stress on internodal length, a scientific methodology entails investigating the influence of growth regulators. Salicylic acid, renowned for its role in plant defence mechanisms, can be strategically administered to regulate internodal growth in unfavourable circumstances. From a scientific perspective, the activation of stress response genes by salicylic acid has been observed to improve a plant's capacity to endure environmental stressors, which could facilitate the attainment of an ideal internodal length. This strategic approach is especially significant in early planting, as it provides a scientific method to enhance the resilience of the plants against the possible adverse impacts of late frosts on the growth of internodes. In addition, using sodium nitroprusside as a nitric oxide donor offers a scientific approach to enhance internodal length. When sodium nitroprusside is used carefully and deliberately, it impacts important physiological processes, including cell division and elongation, which are essential for the growth of internodes. From a scientific perspective, this application plays a role in determining the most favourable internodal length for late-sown. This is particularly advantageous as it helps promote the plant's rapid growth during a shortened growing season. The intricate utilization of these growth regulators showcases their capacity to regulate the physiological reactions of plants when confronted with environmental stressors linked to deviations from the suggested sowing schedule (Sabourifard et al., 2023; Kamkar et al., 2023; Jahangirlou et al., 2023). The scientific investigation of the impact of environmental stress on the length between nodes in crops provides a comprehensive comprehension of the complex interaction between timing, growth conditions, and vegetative growth. The crop planted early faces the obstacle of late frosts that hinder the development of the spaces between the nodes. The timing of sowing, based on scientific principles, is considered a crucial factor in creating ideal conditions for internodal elongation. Including growth regulators such as salicylic acid and sodium nitroprusside within the scientific methodology presents tactical interventions for augmenting the resilience of plants, thereby impacting internodal length and influencing the overall structural integrity and growth of the crop.

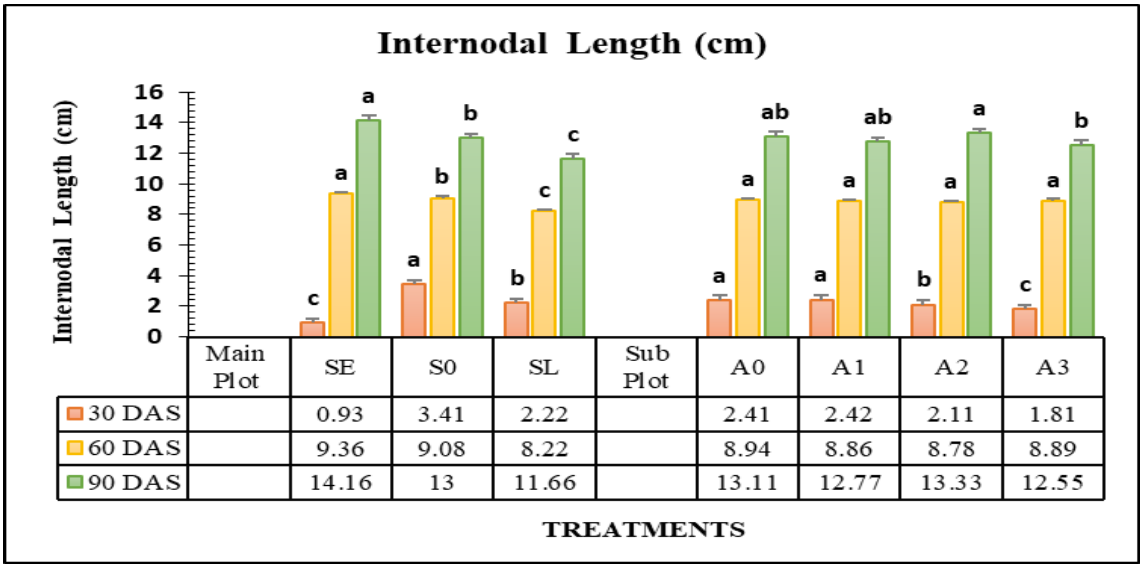
Table 4.1.4.1 Effect of treatments on internodal length (cm) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	**Internodal length (cm)-2022**			**Internodal length (cm)-2023**		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	**0.93**	9.36	14.16	1.14	9.67	15.16
S0 -Optimum sowing	3.41	9.08	13.00	3.62	9.38	14.07
SL -Late sowing	2.22	8.22	11.66	2.43	8.53	11.68
(Agrochemicals)						
A0- Control	2.41	8.94	13.11	2.61	9.24	13.73
A1-Sodium nitroprusside (250 µM/L)	2.42	8.86	12.77	2.63	9.16	13.32
A2-Salicylic acid (150mg/L)	2.11	8.78	13.33	2.32	9.08	14.42
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	1.81	8.89	12.55	2.02	9.29	13.07
CV (Sowing)	3.74	2.38	6.99	3.47	2.31	5.86
CV (Sowing date and agrochemical)	9.15	3.39	5.66	8.40	3.27	5.91
CD (Sowing)	0.09	0.23	1.02	0.03	0.23	0.90
CD (Agrochemicals)	0.19	0.29	0.72	0.19	0.29	0.79

Table 4.1.4.2 Interaction effect of treatments on internodal length (cm) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

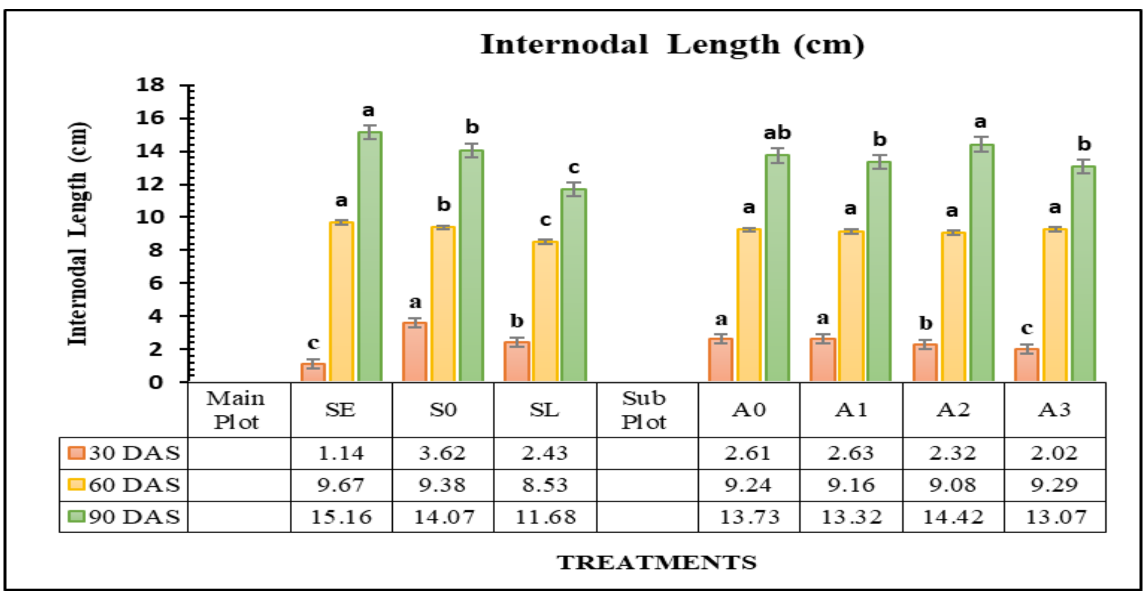
Treatments	Internodal length (cm)-2022			Internodal length (cm)-2023		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
SEA0	0.98^{e}±0.08	9.20^{abc}±0.35	14.33^{ab}±0.58	1.18 ^{e} ±0.08	9.50 ^{abc} ±0.35	15.20 ^{ab} ±0.60
SEA1	0.96^{e}±0.02	9.33^{ab}±0.12	13.67^{bc}±1.53	1.15 ^{e} ±0.02	9.63 ^{ab} ±0.12	14.60 ^{bc} ±1.31
SEA2	0.88^{e}±0.08	9.60^{a}±0.20	15.33^{a}±0.58	1.07 ^{e} ±0.08	9.90 ^{a} ±0.20	16.40 ^{a} ±0.62
SEA3	0.93^{e}±0.03	9.33^{ab}±0.12	13.33^{bcd}±0.58	1.13 ^{e} ±0.03	9.63 ^{ab} ±0.12	14.43 ^{bc} ±0.59
S0A0	3.37±0.38	9.40^{a}±0.20	13.67b±0.58	3.56 ^{b} ±0.38	9.70 ^{a} ±0.20	14.73 ^{b} ±0.57
S0A1	3.40±0.26	8.73^{cd}±0.42	13.00^{bcde}±0.58	3.60 ^{b} ±0.26	9.03 ^{cd} ±0.42	14.10 ^{bc} ±0.10
S0A2	3.77±0.23	9.47^{a}±0.12	13.00^{bcde}±1.00	3.96 ^{a} ±0.23	9.76 ^{a} ±0.12	14.26 ^{bc} ±0.97
S0A3	3.13±0.06	8.73^{cd}±0.46	12.33^{cdef}±0.58	3.33 ^{bc} ±0.06	9.03 ^{cd} ±0.46	13.16 ^{cd} ±0.64
SLA0	2.89±0.06	8.22^{e}±0.19	11.33^{f}±0.58	3.08 ^{c} ±0.06	8.52 ^{e} ±0.19	11.26 ^{e} ±0.64
SLA1	2.92±0.25	8.52^{de}±0.31	11.67^{ef}±0.58	3.12 ^{c} ±0.25	8.82 ^{de} ±0.31	11.26 ^{e} ±0.64
SLA2	1.71±0.12	7.28^{f}±0.19	11.67^{ef}±1.15	1.91 ^{d} ±0.12	7.58 ^{f} ±0.19	12.60 ^{de} ±1.04
SLA3	1.38±0.12	8.89^{bcd}±0.35	12.00^{def}±0.58	1.58 ^{d} ±0.12	9.19 ^{bcd} ±0.35	11.60 ^{e} ±1.04
CV	9.15	3.39	5.66	8.40	3.27	5.91
CD	0.31	0.50	1.48	0.32	0.51	1.45

Figure 4.1.4.1a. Effect of sowing dates and agrochemicals treatments on internodal length (cm) of maize at 30, 60, and 90 DAS during spring season 2022



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		0.93	3.41	2.22		2.41	2.42	2.11	1.81
60 DAS		9.36	9.08	8.22		8.94	8.86	8.78	8.89
90 DAS		14.16	13	11.66		13.11	12.77	13.33	12.55

Figure 4.1.4.2b. Effect of sowing dates and agrochemicals treatments on internodal length (cm) of maize at 30, 60, and 90 DAS during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		1.14	3.62	2.43		2.61	2.63	2.32	2.02
60 DAS		9.67	9.38	8.53		9.24	9.16	9.08	9.29
90 DAS		15.16	14.07	11.68		13.73	13.32	14.42	13.07

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.1.5 Stem diameter (mm): The effect of different sowing dates and agrochemicals on Stem diameter (mm)was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS shown in (Table 4.1.5.1, 4.1.5.2, 4.1.5.3 and 4.1.5.4 and Figure 4.1.5.1a,4.1.5.2b). In 2022 and 2023, there was a significant difference in the percentage of Stem diameter (mm) sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals; it was calculated by comparing all the standard with control. Thus, the percentage pattern in the Stem diameter (mm) was observed at 30, 60, and 90 DAS. In 2022, the early sowing (SE) decreased by 87.07% compared to the optimum sowing (S0), and in the case of late sowing increased, the percentage by 30.03% at 30 DAS. At 60 DAS, early sowing (SE) showed a better result by increasing the rate by 13.33% and late sowing (SL) decreased the rate by 5.71% as compared to the optimum sowing (S0). At 90 DAS, the same trend followed as of 60 DAS: early sowing increased the percentage by 10.20%, and late sowing (SL) decreased the rate by 11.42% compared to the optimum sowing (S0). It was recorded that the combined application of sodium nitroprusside and salicylic acid among agrochemicals showed a better result by increasing the percentage by 35.78% compared to the control (A0) at 30 DAS. AT 60 DAS, the A1 showed the highest percentage, i.e. 9.13%, among all other applied agrochemicals. But at 90 DAS, the rate significantly increased in the A2 by 8.26%, followed by A1 and A3, i.e. 6.27% and 2.30%, respectively, compared to A0. In 2023, it was recorded that early and late sowing decreased the percentage by 85.12% and 41.87%, respectively, compared to the optimum sowing (S0) at 30 DAS. At 60 DAS, the SE and SL decreased the percentage by 17.10% and 30.16%, respectively, compared to optimum sowing (S0). At 90 DAS early sowing (SE), the percentage increased by 6.72% compared to the optimum sowing (S0). It was also recorded that among applied agrochemicals, A1 increased the rate by 9.95% compared to A0 at 30 DAS and 60 DAS; the combined application showed a better result by increasing the percentage by 0.07% compared to control. But at 90 DAS, the A2 led the better effect, having the highest rate, i.e.4.50%, followed by A1, i.e. 2.45%, respectively, when compared with the control (A0). Within the domain of crop cultivation, the diameter of the stem plays a crucial role as a fundamental measure for assessing a plant's reaction to various environmental stress factors. This study examines the intricate mechanisms underlying the variation in crop stem circumference when exposed to untimely sowing, before or after the optimal planting timeframe, compared to the prescribed planting schedule. Comprehending the scientific intricacies associated with stem development is paramount in elucidating the intricate interplay among environmental factors, timing of germination, and subsequent phases of vegetative growth. The premature planting of seeds renders the emerging seedlings vulnerable to various environmental stressors, which substantially affect the diameter of the stem. Late spring frost events present a significant risk, which can impede the expansion of stems and restrict the overall diameter of the plant's primary stem. From a scientific perspective, it has been observed that exposure to cold temperatures can interfere with essential cellular processes that are crucial for the development of stem cells. These processes include cell division and enlargement. The effects of cold stress are evident in the diminished diameter of the stems of crops planted early, affecting their structural strength and overall growth of foliage. On the other hand, sowing crops later than usual introduces specific environmental stress factors that impact the diameter of the stems (Yuee Liu et al., 2023; Wang et al., 2023; Bernzen et al., 2023; Jin-gui et al., 2023; Wu et al., 2023). The compressed duration of the growing season exerts considerable pressure on plants to accelerate the process of stem expansion. From a scientific standpoint, the shortened period could lead to a decrease in the diameter of the stem. This could occur as the plants accelerate their growth during the vegetative phase to allocate more resources towards reproductive activities. The ability of crops to maximise stem diameter and achieve the desired thickness is hindered by the tangible limitations imposed by time limitations. The intricate scientific aspects of this process highlight the importance of maintaining a delicate equilibrium in stem development when faced with different environmental stressors that arise from deviating from the suggested timing for sowing. The timing of sowing is considered a crucial variable in the scientific study of stem girth, as it determines the most favourable conditions for crop development. The synchronization corresponds to advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which contribute to the effective expansion of stems. From a scientific perspective, this synchronisation facilitates the timely initiation of cellular processes, such as stem cell division and growth. The suggested timing establishes the foundation for attaining an ideal stem circumference, a crucial factor in the plant's structural stability and overall development. To address the effects of environmental stress on stem girth, a scientific methodology entails investigating the influence of growth regulators. Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate stem growth in unfavourable circumstances. From a scientific perspective, activating stress response genes by salicylic acid can enhance a plant's capacity to endure environmental challenges, which may facilitate the growth of an optimal stem girth. This strategic approach is especially pertinent for crops that are planted early, as it provides a scientific method to enhance the resilience of plants against the potential adverse impacts of late frosts on the growth of stems. In addition, using sodium nitroprusside as a donor of nitric oxide offers a scientific intervention to enhance the diameter of stems. When sodium nitroprusside is applied carefully and deliberately, it impacts vital physiological processes, including cell division and enlargement, which are fundamental to the growth of stems. From a scientific perspective, this application plays a role in determining the ideal stem circumference, which is especially advantageous for crops that are sown later and need to promote vegetative growth within a limited growing period. The intricate utilization of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronted with environmental stressors linked to deviations from the suggested sowing schedule. The investigation of environmental stress on stem girth in crops from a scientific perspective provides a holistic comprehension of the complex dynamics involving timing, growth conditions, and vegetative growth(Ying Guo et al., 2023; Wang et al., 2023; Bacenetti et al., 2023; Zhao, et al., 2023; Yessoufou et al., 2023). Crops that are sown early face the obstacle of late frosts that hinder the development of their stems. In contrast, crops planted late encounter the difficulty of a shortened growing season that affects the ideal thickness of their stems. Establishing optimal conditions for stem enlargement is contingent upon adhering to the recommended sowing timing based on scientific principles. Including growth regulators such as salicylic acid and sodium nitroprusside within the scientific framework presents tactical interventions aimed at augmenting the robustness of crops, thereby exerting an influence on the diameter of the stem and moulding the overall structural soundness and development of the crop.

Table 4.1.5.1 Effect of treatments on stem diameter (mm) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	**Stem diameter (mm)-2022**			**Stem diameter (mm)-2023**		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	0.34	23.80	27.00	0.54	25.20	35.08
S0 -Optimum sowing	2.63	21.00	24.50	3.63	30.40	32.87
SL -Late sowing	3.42	19.80	21.70	2.11	21.23	30.61
CV Alpha at 0.05						
(Agrochemicals)						
A0- Control	1.91	21.90	23.90	2.11	25.96	32.62
A1-Sodium nitroprusside (250 µM/L)	2.12	23.90	25.40	2.32	25.33	33.42
A2-Salicylic acid (150mg/L)	1.90	23.70	26.00	2.10	25.18	34.09
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	2.59	21.90	24.50	1.84	25.98	31.27
CV (Sowing)	46.98	8.63	6.58	21.58	8.16	3.84
CV (Sowing date and agrochemical)	74.73	6.82	7.89	**16.07**	6.45	4.15
CD (Sowing)	1.13	0.23	0.18	0.51	2.36	1.43
CD (Agrochemicals)	1.57	0.16	0.19	0.33	1.63	1.34

Table 4.1.5.2 The interaction effect of treatments on stem diameter (mm) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Stem diameter (mm)-2022			Stem diameter (mm)-2023		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
SEA0	0.32^{c}±0.08	23.00^{de}±0.02	26.30^{cd}±0.61	0.52 ^{f} ±0.07	24.4 ^{de} ±0.59	34.6 ^{e} ±2.30
SEA1	0.32^{c}±0.09	23.80^{d}±0.06	26.60^{b}±0.15	0.52 ^{f} ±0.07	25.2 ^{d} ±0.68	38.9 ^{bc} ±2.56
SEA2	0.39^{c}±0.04	24.30^{cd}±0.08	30.90^{a}±0.01	0.60 ^{f} ±0.07	25.7 ^{cd} ±0.62	35.9 ^{a} ±1.97
SEA3	0.33^{c}±0.08	27.40^{d}±0.11	27.90^{ab}±0.16	0.53 ^{f} ±1.68	25.5±5.18d	36.0±1.25b
S0A0	3.37^{ab}±0.38	33.30^{a}±0.15	34.80^{b}±0.06	3.57 ^{ab} ±0.29	34.7 ^{a} ±5.06	31.1 ^{b} ±2.96
S0A1	3.40^{ab}±0.26	23.10^{cd}±0.38	25.10^{cd}±0.15	3.60 ^{ab} ±0.30	26.7 ^{cd} ±2.07	33.4 ^{de} ±1.63
S0A2	3.77^{ab}±0.23	25.70^{bc}±0.23	27.54^{bc}±0.05	3.97 ^{a} ±0.36	29.1 ^{bc} ±6.89	31.0 ^{cd} ±1.67
S0A3	3.17^{ab}±0.06	28.30^{b}±0.25	30.52^{cd}±0.61	3.37 ^{bc} ±0.76	31.1 ^{b} ±3.22	30.9 ^{e} ±1.21
SLA0	2.05^{abc}±0.71	17.33^{f}±0.15	22.90^{cd}±0.12	2.25 ^{d} ±0.81	18.7 ^{f} ±2.28	34.6 ^{e} ±2.35
SLA1	2.64^{abc}±0.94	22.70^{de}±0.15	26.60^{b}±0.15	2.84 ^{c} ±0.84	24.1 ^{de} ±1.51	29.9 ^{bc} ±2.82
SLA2	1.55^{bc}±0.06	19.30^{f}±0.15	21.90^{d}±0.11	1.75 ^{de} ±0.09	20.7 ^{f} ±1.73	27.0 ^{e} ±2.50
SLA3	1.41^{a}±0.05	20.00^{ef}±0.17	23.60^{e}±1.01	1.61 ^{e} ±0.05	21.4 ^{ef} ±2.76	34.6 ^{f} ±2.78
CV	74.73	6.82	7.89	16.07	6.45	4.15
CD	2.61	0.33	0.34	0.70	3.37	2.45

Figure 4.1.5.1a. Effect of sowing dates and agrochemicals treatments on stem diameter (mm) of maize at 30, 60, and 90 DAS during spring season 2022

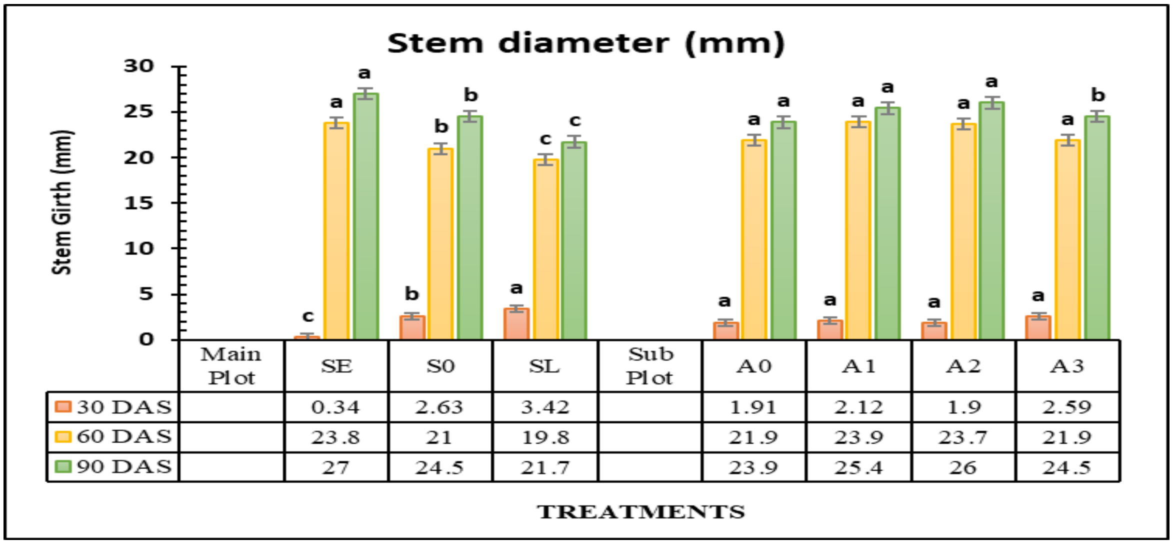
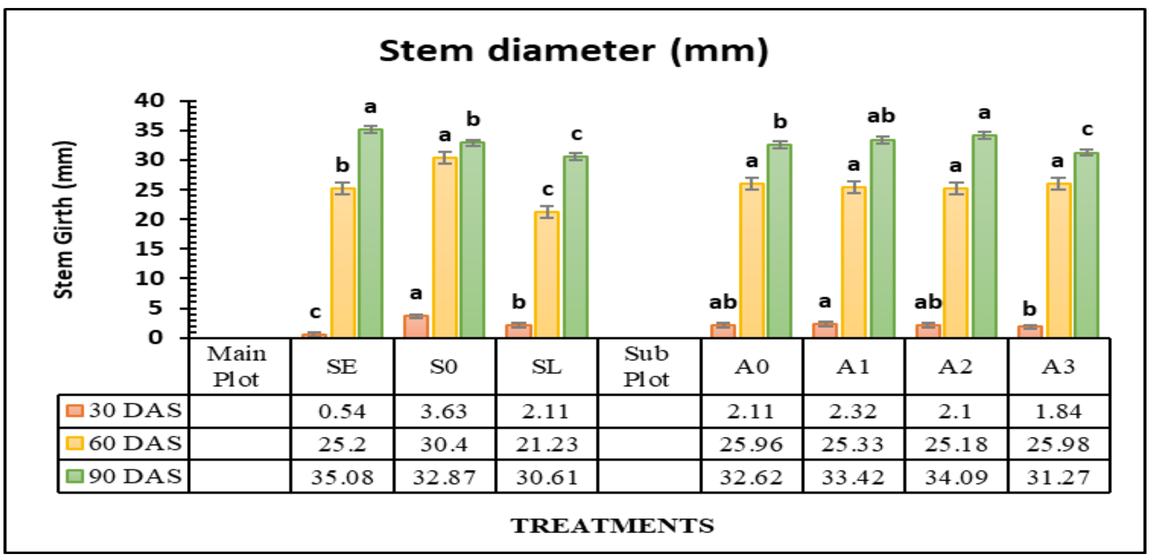


Figure 4.1.5.2b. Effect of sowing dates and agrochemicals treatments on stem diameter (mm) of maize at 30, 60, and 90 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.1.6 Leaf area (cm^2): The impact of sowing dates and agrochemicals on Leaf area (cm^2) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS shown in (Table 4.1.6.1, 4.1.6.2, and Figure 4.1.6.1a, 4.1.6.2b). In 2022 and 2023, there was a significant difference in the percentage of Leaf area (cm^2) sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals; it was calculated by comparing all the mean with control. Thus, the percentage pattern in the Leaf area (cm^2) was observed at 30, 60, and 90 DAS. In 2022, the late sowing (SL) showed the highest percentage, 32.05%, and early sowing had 0.26% compared to the optimum sowing (S0) at 30 DAS. T 60 DAS, both early (SE) and late sowing (SL), decreased the percentage by 36.44% and 65.87%, respectively, when compared to optimum sowing (S0). Similarly, at 90 DAS, the same trends followed as of 60 DAS in early and late sowing, the percentage by 36.44% and 65.87%, respectively, compared to optimum sowing (S0). It was also recorded that A3 showed a better result among applied agrochemicals, which significantly increased the percentage by 11.09% and A2 by 2.26%, respectively, when compared with A0 at 30 DAS. At 60 DAS, A1 had the highest rate, i.e., 37.07%, followed by A3 and A2 by 20.92% and 19.02%, respectively, compared to A0. Similarly, at 90 DAS, A1 had the highest percentage, 22.22%, followed by A2 at 17.65%, respectively, compared to the A0. In the year 2023, it was observed that late sowing (SL) had the highest percentage, i.e., 31.08% and early sowing (SE) also showed a better result by increasing the rate by 0.24% as compared to the optimum sowing (S0) at 30 DAS. AT 60 DAS, it was observed that early and late sowing decreased the percentage by 11.10 % and 16.35%, respectively, compared to the optimum sowing (S0). Similarly, at 90 DAS, early and late sowing decreased the percentage by 36.41% and 65.82%, respectively, compared to the optimum sowing (S0). It was observed that A3 showed the highest rate, 11.01%, followed by A2, i.e.,2.15, respectively, when compared to A0 at 30 DAS. AT 60, DAS A1 had the highest rate, i.e.,36.99%, followed by A3 and A2, i.e., 26.02% and 25.98%, respectively, compared to the control (A0). At 90 DAS, the A3 had the highest percentage, i.e., 23.79%, compared to the control (A0). Within the domain of agricultural cultivation, the leaf area of a plant assumes a pivotal function in the processes of photosynthesis, nutrient assimilation, and the overall well-being of the plant. Compared to the recommended planting timeframe, this study examines the intricate dynamics of leaf area in crops when subjected to untimely sowing, either in advance or delayed. Comprehending the scientific complexities associated with leaf area development is of utmost importance to elucidate the intricate interactions among environmental factors, timing of germination, and subsequent phases of vegetative growth. The premature planting of seeds renders emerging seedlings vulnerable to various environmental stressors, substantially affecting the leaf area. Late spring frosts present a significant hazard that has the potential to undermine the growth and maturation of foliage. From a scientific standpoint, it has been observed that being exposed to cold temperatures can interfere with essential cellular processes that are responsible for the development of leaf area. These processes include cell division and the synthesis of chlorophyll. The repercussions of cold stress are evident in a decrease in the leaf area of crops sown early. This subsequently affects their ability to carry out photosynthesis and assimilate nutrients effectively. On the other hand, delayed sowing of crops introduces specific environmental stress factors that impact the leaf area (Wang et al., 2023; Wang et al., 2023; Xiu-chun Dong et al., 2023; Rahimi-Moghaddam et al., 2023; Chandel et al., 2023). The compressed duration of the growing season exerts considerable stress on plants, compelling them to accelerate the process of leaf expansion. From a scientific standpoint, the tight time frame could decrease leaf area as plants expedite their growth during the vegetative stage to allocate resources towards reproductive activities. The ability of crops to maximize leaf area and achieve the desired canopy density is hindered by the tangible limitations imposed by time constraints. The intricate scientific aspects of this process highlight the importance of maintaining a delicate equilibrium in leaf area development when faced with different environmental stressors that arise from deviating from the suggested timing for sowing. The timing of sowing is considered a crucial factor in the scientific study of leaf area, as it determines the most favourable conditions for crop growth. The synchronization corresponds with advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which contribute to the optimal expansion of leaves. The suggested timing establishes the foundation for attaining an ideal leaf area, a crucial factor in the plant's photosynthetic efficiency and overall development. To alleviate the effects of environmental stress on leaf area, a scholarly methodology entails investigating the influence of growth regulators.

Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate leaf growth in the face of unfavourable circumstances (Yue Zhang et al., 2023; Etesami et al., 2023; Jaggi et al., 2023; Du et al., 2023; Fu et al., 2023). From a scientific perspective, salicylic acid's activation of stress response genes has been observed to improve a plant's capacity to endure environmental challenges, which may facilitate the growth of an ideal leaf area. In addition, sodium nitroprusside, which acts as a donor of nitric oxide, offers a scientific intervention for optimizing leaf area. When sodium nitroprusside is used carefully and deliberately, it impacts essential physiological processes, including the development of chloroplasts and the expansion of cells, which are fundamental to the growth of leaves. From a scientific perspective, this application plays a role in determining the ideal leaf area, which is especially advantageous for crops that are planted late and need to promote vegetative growth within a limited growing season. In summary, the scientific investigation of the impact of environmental stress on leaf area in crops provides a holistic comprehension of the complex dynamics involving timing, growth conditions, and vegetative growth. Crops planted early face the obstacle of late frosts that hinder the development of their leaves, whereas crops that are planted late struggle with the pressure of a shortened growing season that affects the ideal leaf area (Tang et al., 2023; Zahedi et al., 2023; Changjie et al., 2023; Pal et al., 2023; Zhe Li and Ahammed 2023; Gunasekera and Ratnasekera 2023; Singh et al., 2023; Paravar et al., 2023; Khan and Quintanilla 2023; Fatima et al., 2023; Prakash 2023; Hussain et al., 2023). The timing of sowing, based on scientific principles, plays a crucial role in creating the most favourable conditions for leaf expansion. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into the scientific methodology provides strategic interventions for improving the resilience of crops. These interventions have the potential to impact leaf area, as well as shape the overall photosynthetic efficiency and growth of the crop. The ongoing scientific exploration in various disciplines has shed light on the intricate mechanisms governing the vegetative stages of crop growth, particularly leaf development and the impact of environmental stressors.

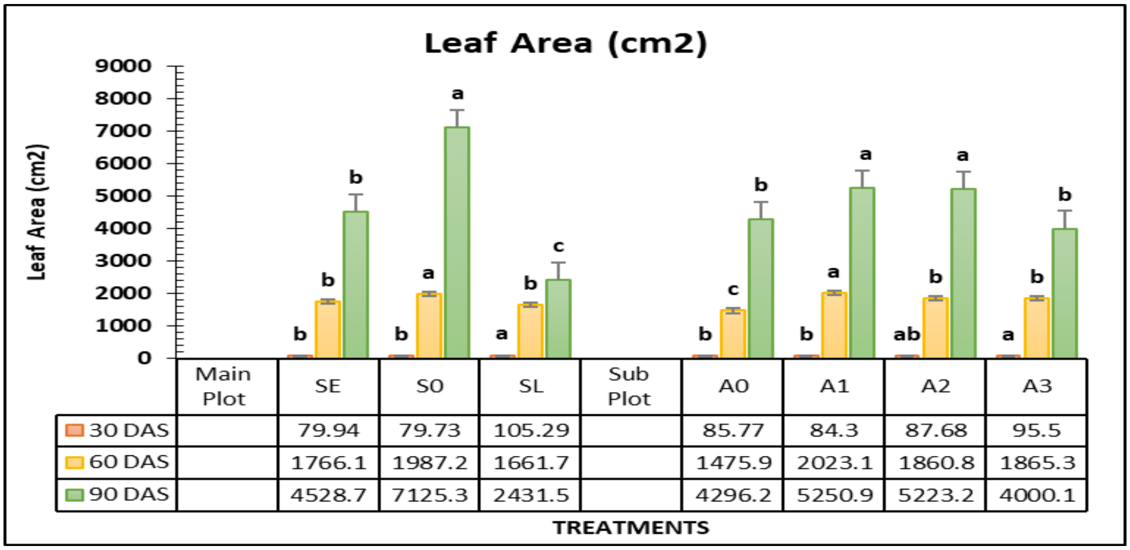
Table 4.1.6.1 Effect of treatments on leaf area (cm^2) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	leaf area (cm^2)-2022			leaf area (cm^2)-2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	79.94	1766.10	4528.70	82.43	1769.4	4534.2
S0 -Optimum sowing	79.73	1987.20	7125.30	82.23	1990.5	7130.8
SL -Late sowing	105.29	1661.70	2431.50	107.79	1665.0	2437.0
(Agrochemicals)						
A0- Control	85.77	1475.90	4296.20	88.277	1479.2	5256.4
A1-Sodium nitroprusside (250 µM/L)	84.30	2023.10	5250.90	86.808	2026.4	4302.1
A2-Salicylic acid (150mg/L)	87.68	1860.80	5223.20	90.181	1863.6	5238.7
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	95.50	1865.30	4000.10	98.003	1864.1	4005.6
CV (Sowing)	17.56	9.57	12.51	17.08	9.55	12.50
CV (Sowing date and agrochemical)	10.32	8.47	6.55	10.04	8.46	6.55
CD (Sowing)	17.58	195.77	666.00	17.75	194.01	665.01
CD (Agrochemicals)	9.02	151.50	304.80	9.05	152.01	303.02

Table 4.1.6.2 The interaction effect of treatments on leaf area (cm^2) of Maize at 30, 60, and 90 DAS during spring season 2022 and 2023

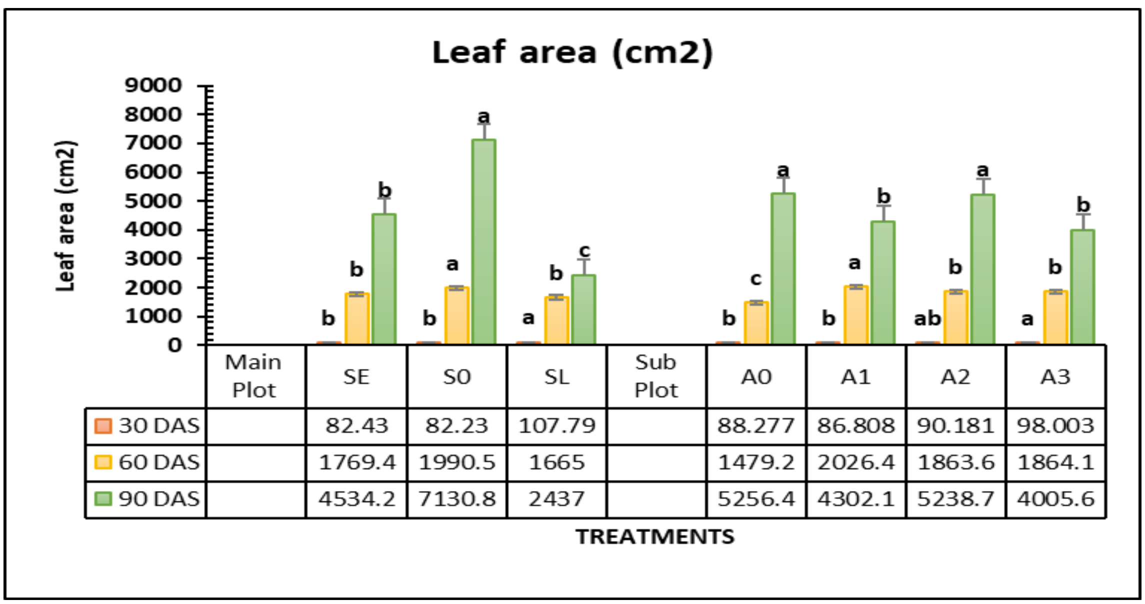
Treatments	**leaf Area (cm^2)-2022**			**leaf Area (cm^2)-2023**		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
SEA0	76.62^{ef}±8.05	1569.23^{cd}±21.25	4591.67^{e}±10.97	71.65 ^{ef} ±15.97	1533.5 ^{cd} ±25.95	4988.5 ^{cd} ±49.51
SEA1	76.99^{cdef}±12.90	1904.10^{ab}±74.47	4466.00^{e}±29.62	79.49 ^{cdef} ±12.90	1914.5 ^{ab} ±37.95	4494.3 ^{de} ±80.84
SEA2	84.00^{bcdef}±1.31	1541.47^{cd}±31.68	4934.23^{cd}±67.49	86.50 ^{bcdef} ±1.31	1540.2 ^{cd} ±35.49	4416.2 ^{e} ±67.34
SEA3	89.60^{bcd}±6.04	2086.00^{a}±11.43	4926.17^{de}±51.39	92.10 ^{bcd} ±6.04	2089.3 ^{a} ±11.43	4237.9 ^{e} ±42.45
S0A0	67.27^{f}±21.75	1676.83^{bc}±10.54	9577.67^{a}±41.31	69.77 ^{f} ±21.75	1643.8 ^{bc} ±52.40	9372.4 ^{a} ±26.25
S0A1	71.4^{def}±12.23	1895.90^{a}±56.30	5782.23^{c}±18.21	73.97 ^{def} ±12.23	2062.5 ^{a} ±13.71	8173.5 ^{b} ±56.22
S0A2	86.73^{bcde}±8.98	2195.20^{a}±53.11	7972.17^{b}±12.00	89.23 ^{bcde} ±8.98	2103.7 ^{a} ±31.02	5692.8 ^{c} ±61.36
S0A3	93.43^{bc}±14.83	2148.77^{a}±42.71	5260.30^{cd}±36.89	95.93 ^{bc} ±14.83	2152.1 ^{a} ±42.71	5284.7 ^{cd} ±53.45
SLA0	120.91^{a}±3.28	1256.87^{d}±33.61	2050.67^{h}±41.00	123.41 ^{a} ±3.28	1260.2 ^{d} ±33.61	2975.5 ^{f} ±38.23
SLA1	104.47^{b}±0.98	2061.03^{a}±23.08	3193.63^{f}±58.48	106.97 ^{b} ±0.98	2102.1 ^{b} ±21.36^{a}	2554.1 ^{fg} ±46.12
SLA2	92.31^{bcd}±1.61	2068.50^{a}±27.17	2861.93^{fg}±55.45	94.81 ^{bcd} ±1.61	1946.8 ^{a} ±15.78	2237.7 ^{gh} ±57.75
SLA3	103.48^{b}±2.36	1347.60^{cd}±44.09	2247.17^{gh}±29.79	105.98 ^{b} ±2.36	1350.9 ^{cd} ±21.64	1980.5 ^{h} ±73.65
CV	10.32	8.47	6.55	10.04	8.46	6.55
CD	21.98	297.28	800.46	21.92	298.21	801.25

Figure 4.1.6.1a. Effect of sowing dates and agrochemicals treatments on leaf area (cm^2) of maize at 30, 60, and 90 DAS during spring season 2022



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		79.94	79.73	105.29		85.77	84.3	87.68	95.5
60 DAS		1766.1	1987.2	1661.7		1475.9	2023.1	1860.8	1865.3
90 DAS		4528.7	7125.3	2431.5		4296.2	5250.9	5223.2	4000.1

Figure 4.1.6.2b. Effect of sowing dates and agrochemicals treatments on leaf area (cm^2) of maize at 30, 60, and 90 DAS during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		82.43	82.23	107.79		88.277	86.808	90.181	98.003
60 DAS		1769.4	1990.5	1665		1479.2	2026.4	1863.6	1864.1
90 DAS		4534.2	7130.8	2437		5256.4	4302.1	5238.7	4005.6

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.1.7. Leaf Area Index: The impact of sowing dates and agrochemicals on the Leaf Area Index was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS (Table 4.1.7.1, 4.1.7.2, and Figure 4.1.7.1a,4.1.7.2b). In 2022 and 2023, there was a significant difference in the percentage of Leaf Area Index sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals; it was estimated by comparing all the mean with control. Thus, the percentage pattern in the Leaf Area Index was observed at 30, 60, and 90 DAS. In 2022, it was found that late sowing (SL) increased the percentage by 33.33% compared to optimum sowing at 30 DAS. In the case of early sowing (SE), the rate was decreased by 10.09% and 16.36% at 60 and 90 DAS, respectively, when compared with optimum sowing. It was found that the combined application of agrochemicals (A3) increased the percentage by 12.19%, 21.29%, and 23.85% at 30, 60, and 90 DAS, respectively, as compared to the control (A0). Application salicylic acids (A2) also showed better results by increasing the percentage by 2.85%, 19.64%, and 0.27% at 30, 60, and 90 DAS, respectively, compared to control (A0). In 2023, it was recorded that late sowing (SL) showed the highest increase in percentage, i.e. 30.88, compared to the optimum sowing (S0) at 30 DAS. Similarly, at 60 and 90 DAS, the late sowing decreased the percentage by 16.36% and 65.82%, followed by early sowing (SE0 by 10.90% and 36.53%, respectively) when compared with the optimum sowing (S0). It was found that in applied agrochemicals combined application showed the highest percentage, i.e. 10.95% and 26.01% at 30 and 60 DAS, respectively, compared to control (A0). The application of salicylic acid (A2) also showed a better result by increasing the percentage by 2.73%, 26.01 and 0.45% at 30, 60 and 90 DAS, respectively, compared to the control (A0). But at 60 DAS, the application of sodium nitroprusside showed the highest percentage, i.e. 36.58%, compared to the control (A0). Within the complex domain of crop physiology, the Leaf Area Index (LAI) is a crucial metric for evaluating a plant's reaction to various environmental stressors. This study investigates the intricate dynamics of the Leaf Area Index (LAI) in crops subjected to untimely sowing, either prematurely or delayed, compared to the recommended planting schedule. A comprehensive comprehension of the scientific complexities associated with the Leaf Area Index (LAI) is imperative to elucidate the intricate interactions among environmental factors, timing of germination, and subsequent growth and reproductive processes in plants. The premature planting of seeds exposes emerging seedlings to various environmental stressors, significantly impacting the Leaf Area Index (LAI). Late spring frosts present a considerable risk, which has the potential to impede the ideal growth of leaves. From a scientific perspective, it has been observed that exposure to cold temperatures can interfere with crucial physiological processes, such as leaf initiation and expansion. This interference can impact the overall extent and efficiency of the Leaf Area Index (LAI). The effects of cold stress are evident in the diminished and irregular leaf area index (LAI) observed in crops that are sown early, which in turn hampers their ability to carry out photosynthesis and impairs their subsequent growth. On the other hand, planting crops later than usual introduces specific environmental stressors that impact the Leaf Area Index (LAI). The compressed duration of the growing season exerts substantial pressure on plants to accelerate their vegetative and reproductive growth. From a scientific standpoint, the shortened course could reduce the Leaf Area Index (LAI) as plants accelerate their growth stages to allocate resources towards reproductive activities. The ability of crops to maximize their Leaf Area Index (LAI) is hindered by tangible limitations imposed by temporal constraints. The scientific complexities of this process highlight the importance of maintaining a precise equilibrium to attain an optimal Leaf Area Index (LAI) amidst diverse environmental pressures resulting from deviations in the suggested timing for sowing (Sharma and Kumar 1999; Siddique et al., 2018). The timing of sowing is considered a crucial element in the scientific study of the Leaf Area Index (LAI), as it determines the ideal conditions for crop growth and development. The synchronicity corresponds to advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which contribute to the effective initiation and growth of leaves. From a scientific perspective, this synchronization facilitates the timely activation of genetic and hormonal mechanisms, ultimately resulting in a uniform and optimal Leaf Area Index (LAI). The suggested timing establishes the conditions for attaining an optimal leaf canopy, which is critical in determining the crop's photosynthetic efficiency and overall yield potential. To address the consequences of environmental stress on the Leaf Area Index (LAI), a scientific investigation is undertaken to examine the influence of growth regulators. Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate leaf growth in unfavourable circumstances. From a scientific perspective, the activation of stress response genes by salicylic acid has been found to improve a plant's capacity to endure environmental challenges, which could lead to a more consistent and optimal Leaf Area Index (LAI). This strategic approach is especially pertinent for crops that are planted early, as it provides a scientific method to enhance the resilience of plants against potential adverse impacts of late frost events on the development of leaves. Using sodium nitroprusside as a nitric oxide donor offers a scientific intervention for optimizing LAI. When sodium nitroprusside is used carefully and deliberately, it impacts essential physiological processes, including cell division and elongation, which are fundamental to the development of leaves. From a scientific standpoint, this application plays a role in determining the most favourable Leaf Area Index (LAI), which is particularly advantageous for crops that are sown late and need to enhance both vegetative and reproductive growth despite having a shorter growing season. The intricate utilisation of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from suggested sowing schedules. The scientific investigation of the impact of environmental stress on Leaf Area Index (LAI) in crops thoroughly comprehends the complex interaction between timing, growth conditions, and vegetative and reproductive growth. Crops that are sown early face the obstacle of late frosts, which hinder the achievement of an optimal Leaf Area Index (LAI). On the other hand, crops that are sown late encounter the challenge of a shortened growing season, affecting leaf cover development. Determining the appropriate timing for sowing, based on scientific principles, is crucial in creating favourable conditions to achieve an optimal Leaf Area Index (LAI). Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions that can effectively improve the resilience of crops. These interventions can influence the Leaf Area Index (LAI), shaping the crop's photosynthetic capacity and yield potential.

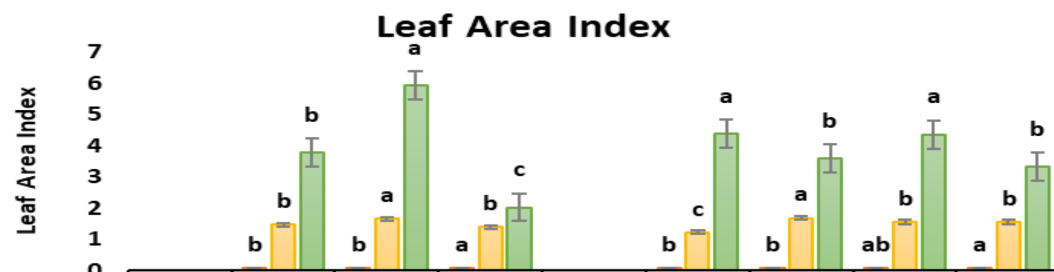
Table 4.1.7.1 Effect of treatments on leaf area index at 30, 60 and 90 DAS during spring season 2022 and 2023

Treatments	**Leaf Area index-2022**			**Leaf Area index-2023**		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	0.06	1.47	3.77	0.068	0.068	3.77
S0 -Optimum sowing	0.06	1.65	5.93	0.068	0.068	5.94
SL -Late sowing	0.08	1.38	2.02	0.089	0.089	2.03
(Agrochemicals)						
A0- Control	0.071	1.22	4.37	0.073	1.23	4.38
A1-Sodium nitroprusside (250 µM/L)	0.070	1.68	3.58	0.072	1.68	3.58
A2-Salicylic acid (150mg/L)	0.073	1.55	4.36	0.075	1.55	4.36
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	0.0799	1.55	3.33	0.081	1.55	3.33
CV (Sowing)	17.56	9.57	12.51	17.08	17.08	12.50
CV (Sowing date and agrochemical)	10.32	8.47	6.55	10.04	8.46	6.55
CD (Sowing)	0.014	0.163	0.555	0.015	0.162	0.554
CD (Agrochemicals)	0.007	0.126	0.254	0.008	0.125	0.253

Table 4.1.7.2 The interaction effect of treatments on leaf area index of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

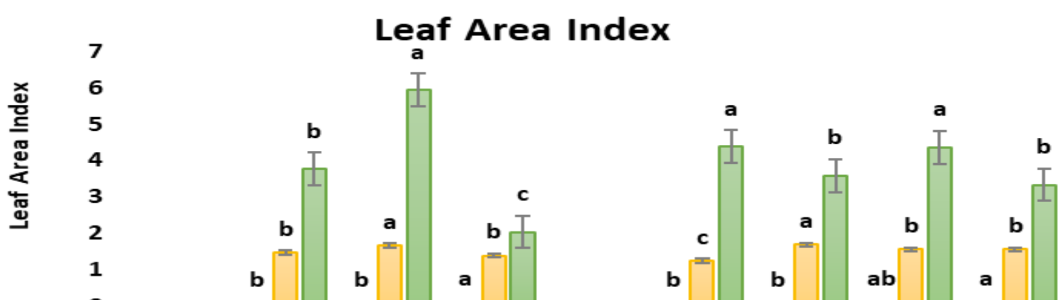
Treatments	Leaf Area index-2022			Leaf Area index-2023		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
SEA0	0.06^{ef}±0.01	1.28^{cd}±0.07	3.68^{e}±0.32	0.06^{ef}±0.01	1.28^{cd}±0.07	3.68^{e}±0.32
SEA1	0.07^{cdef}±0.01	1.60^{ab}±0.22	3.53e±0.45	0.07^{cdef}±0.01	1.60^{ab}±0.22	3.53e±0.45
SEA2	0.07^{bcdef}±0.00	1.28^{cd}±0.05	4.16^{cd}±0.19	0.07^{bcdef}±0.00	1.28^{cd}±0.05	4.16^{cd}±0.19
SEA3	0.08^{bcd}±0.01	1.74^{a}±0.01	3.75^{de}±0.38	0.08^{bcd}±0.01	1.74^{a}±0.01	3.75^{de}±0.38
S0A0	0.06^{f}±0.02	1.37^{bc}±0.06	7.81^{a}±0.22	0.06^{f}±0.02	1.37^{bc}±0.06	7.81^{a}±0.22
S0A1	0.06^{def}±0.01	1.72^{a}±0.25	4.74c±0.05	0.06^{def}±0.01	1.72^{a}±0.25	4.74c±0.05
S0A2	0.07^{bcde}±0.01	1.75^{a}±0.16	6.81^{b}±0.51	0.07^{bcde}±0.01	1.75^{a}±0.16	6.81^{b}±0.51
S0A3	0.08^{bc}±0.01	1.79^{a}±0.05	4.40^{cd}±0.19	0.08^{bc}±0.01	1.79^{a}±0.05	4.40^{cd}±0.19
SLA0	0.10^{a}±0.00	1.05^{d}±0.03	1.65h±0.06	0.10^{a}±0.00	1.05^{d}±0.03	1.65h±0.06
SLA1	0.09^{b}±0.00	1.75^{a}±0.08	2.48^{f}±0.35	0.09^{b}±0.00	1.75^{a}±0.08	2.48^{f}±0.35
SLA2	0.08^{bcd}±0.00	1.62a±0.15	2.13^{fg}±0.46	0.08^{bcd}±0.00	1.62a±0.15	2.13^{fg}±0.46
SLA3	0.09^{b}±0.00	1.13^{cd}±0.09	1.86^{gh}±0.28	0.09^{b}±0.00	1.13^{cd}±0.09	1.86^{gh}±0.28
CV	10.32	8.47	6.55	10.04	8.46	6.55
CD	0.018	0.247	0.667	0.0184	0.246	0.665

Figure 4.1.7.1a. Effect of sowing dates and agrochemicals treatments on leaf area index at 30, 60 and 90 DAS during spring season 2022



	Main Plot (Sowing Date)	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		0.06	0.06	0.08		0.071	0.07	0.073	0.0799
60 DAS		1.47	1.65	1.38		1.22	1.68	1.55	1.55
90 DAS		3.77	5.93	2.02		4.37	3.58	4.36	3.33

Figure 4.1.7.2b. Effect of sowing dates and agrochemicals treatments on leaf area index at 30, 60 and 90 DAS during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		0.068	0.068	0.089		0.073	0.072	0.075	0.081
60 DAS		1.47	1.65	1.38		1.23	1.68	1.55	1.55
90 DAS		3.77	5.94	2.03		4.38	3.58	4.36	3.33

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.1.8 Days to 50% tasseling: The effect of different sowing dates and agrochemicals on Days to 50% tasseling was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS shown in (Table 4.1.8.1, 4.1.8.2 and Figure 4.1.8.1a,4.1.8.2b). In 2022 and 2023, there was a significant difference in the percentage of Days to 50% tasseling sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Days to 50% Tasseling was observed at 30, 60, and 90 DAS. In 2022, it was recorded that early (SE) and late sowing decreased the days to 50% tasseling by 20.19 % and 11.06 %, respectively, compared to the optimum sowing. It means that late sowing (SL) took fewer days for the 50 % tasseling. In the case of applied agrochemicals, the combined application of sodium nitroprusside and salicylic acid (A3) decreased the percentage by 2.81% compared to other used agrochemicals. The interaction effect of sowing and agrochemicals also showed the better result in which SLA0 showed the better result by decreasing the days to 50% tasseling by 59.33 followed by SLA3, SLA1, SLA2, SEA0, SE3, SEA2, S0A0, S0A3, S0A2 AND S0A1 by 62.00, 62.66, 63.66,69.00,69.33,71.00,76.00,76.66,78.33 and 79.33 respectively. In the year 2023, late sowing (SL) showed a better result by decreasing the percentage by 19.74%, followed by early sowing (SE) by 10.87% as compared to the optimum sowing (S0). In the case of applied agrochemicals, the combined application of sodium nitroprusside and salicylic acid showed a better result by decreasing the percentage by 2.75%, followed by A1 and A2 by 4.68% and 5.34%, respectively, as compared to control (A0). The interaction effect of sowing dates and agrochemicals showed a better result by decreasing the days to 50% tasseling in SLA0, followed by SLA3, SLA1, and SLA2 by 60.66,63.33,64.33, and 65.00, respectively. Within crop cultivation, the period required for a plant to reach 50% tasseling, a significant stage of development, serves as a vital measure for evaluating the plant's reaction to various environmental pressures. This study examines the intricate dynamics of the time it takes for crops to reach 50% tasseling when they are sown either too early or too late, in contrast to the optimal planting timeframe. Comprehending the scientific complexities associated with this temporal dimension is imperative to decipher the intricate interactions among environmental factors, the timing of germination, and the subsequent phases of vegetative and reproductive development. When seeds are planted before the optimal time, the resulting seedlings become susceptible to various environmental stressors that significantly impact the duration for the plants to reach 50% tasseling. Late spring frost events present a considerable risk, potentially hindering the prompt commencement of reproductive processes. From a scientific perspective, it can be observed that exposure to cold temperatures has the potential to interfere with significant physiological processes. These processes include the development of floral primordia and the functioning of hormonal signaling pathways. As a result, the synchronized transition to the tasseling stage may be adversely affected. The effects of cold stress are observed in a prolonged period required to achieve 50% tasseling in crops sown early, impacting the overall reproduction efficiency and the potential yield. On the other hand, delayed sowing introduces specific environmental stress factors that affect the duration until 50% of tasseling occurs in crops. The compressed course of the growing season exerts substantial pressure on plants to accelerate their reproductive development. From a scientific standpoint, the shortened time frame may lead to a decreased duration required for plants to reach 50% tasseling as they expedite their progress through the vegetative stage to allocate resources towards reproductive functions. The ability of crops to effectively manage the timing of tasseling is hindered by the tangible limitations imposed by temporal constraints(Singh et al., 2023; Graf et al., 2023; XU et al., 2023; Kaya et al., 2023; Trejo et al., 2023). The intricate scientific aspects of this process highlight the importance of maintaining a delicate equilibrium to ensure a timely reproductive transition, especially when faced with environmental stressors that may arise from deviating from the recommended sowing timing. The timing of sowing is considered a crucial variable in scientific research on the time it takes for crops to reach 50% tasseling. This factor is important as it determines the ideal conditions for crop growth and reproductive maturation. The synchronization corresponds with advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which contribute to a proficient reproductive shift. From a scientific standpoint, this synchronization facilitates the prompt initiation of genetic and hormonal mechanisms, resulting in a harmonized and consistent advancement towards the tasseling phase. The suggested timing establishes the foundation for attaining an ideal timeframe to achieve 50% tasseling, a critical factor in the plant's reproductive efficacy and overall yield capacity. To address the effects of environmental stress on the duration of the days required for 50% tasseling, a scholarly approach entails investigating the potential influence of growth regulators. Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate reproductive development in the face of unfavourable circumstances. From a scientific perspective, salicylic acid's activation of stress response genes has been found to improve a plant's capacity to endure various environmental challenges. This process may facilitate a more coordinated and punctual progression towards the tasseling stage. This strategic approach is especially pertinent for crops that are planted early, as it provides a scientific method to enhance the resilience of plants against the potentially harmful impacts of late frosts on their reproductive growth (Yuvaraj et al., 2023; Asgher et al., 2023; Mansour 2023; Yan et al., 2023; Yu et al., 2023; Shi et al., 2023; Lone et al., 2023; Peng et al., 2023; Yu et al., 2023). In addition, using sodium nitroprusside as a nitric oxide donor offers a scientific intervention to optimize the duration required for 50% tasseling. When sodium nitroprusside is used carefully and deliberately, it impacts critical physiological processes essential for reproductive development, including the initiation of floral primordia and hormonal regulation. From a scientific perspective, this application plays a role in determining the ideal timeframe required to achieve 50% tasseling. This is particularly advantageous for crops sown late and must accelerate their reproductive growth within a limited growing season. The intricate utilization of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronted with environmental stressors linked to deviations from the suggested sowing schedule. In summary, the scientific investigation of the impact of environmental stress on the duration until 50% tasseling in crops provides a thorough comprehension of the complex dynamics involving timing, growth conditions, and reproductive maturation. Crops planted early face the obstacle of late frosts, which can promptly hinder their progression to the tasseling stage. On the other hand, crops planted late experience the difficulty of a shortened growing season, which affects the timing of their reproductive development. Determining the appropriate timing for sowing, based on scientific principles, is crucial in creating ideal circumstances for achieving 50% tasseling. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into the scientific methodology provides strategic interventions to improve crops' resilience. These interventions have the potential to impact the duration required for 50% tasseling, as well as influence the overall reproductive success and yield potential of the crop. Investigating reproductive development and environmental stressors in the agricultural domain provides valuable insights into the complex mechanisms regulating crop cultivation's reproductive phases (Nirwan et al., 2023; Qureshi et al., 2023; Laribi et al., 2023; Yadav and Singh 2023).

Table 4.1.8.1 Effect of treatments on days to 50 % tasseling of maize at 60 DAS during spring season 2022 and 2023

Treatments	**Days to 50 % Tasseling 2022**	**Days to 50 % Tasseling 2023**
Sowing Date		
SE -Early sowing	69.00	70.33
S0 -Optimum sowing	77.58	78.91
SL -Late sowing	61.91	63.33
Agrochemical		
A0- Control	67.33	68.66
A1-Sodium nitroprusside (250 µM/L)	70.44	71.88
A2-Salicylic acid (150mg/L)	71.00	72.33
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	69.33	70.55
Alpha at 0.05		
CV (Sowing date and agrochemical)	1.70	1.71
CV (Sowing)	0.85	0.78
CD (Agrochemical)	0.61	0.68
CD (Sowing)	1.16	1.20

Table 4.1.8.2 The interaction effect of sowing dates and agrochemicals treatments on days to 50 % tasseling of maize at 60 DAS during spring season 2022 and 2023

Treatments	Days to 50 % Tasseling-2022	Days to 50 % Tasseling-2023
SEA0	66.67^{e}±1.53	68.00^{e}±1.97
SEA1	69.33^{d}±0.58	70.67^{d}±1.38
SEA2	71.00^{d}±1.00	72.33^{d}±1.63
SEA3	69.00^{d}±1.00	70.33^{d}±4.22
S0A0	76.00^{c}±2.00	77.33^{c}±2.45
S0A1	79.33^{a}±0.58	80.67^{a}±0.75
S0A2	78.33^{ab}±0.58	79.67^{ab}±1.47
S0A3	76.67^{bc}±1.15	78.00^{bc}±9.56
SLA0	69.33^{d}±0.58	60.67^{g}±2.07
SLA1	62.67^{f}±0.58	64.33^{f}±1.37
SLA2	63.67f±1.53	65.00^{f}±1.72
SLA3	62.00^{f}±1.00	63.33^{f}±1.15
CV	1.70	1.71
CD	1.84	1.92

Figure 4.1.8.1a. Effect of sowing dates and agrochemicals treatments on days to 50 % tasseling of maize at 60 DAS during spring season 2022

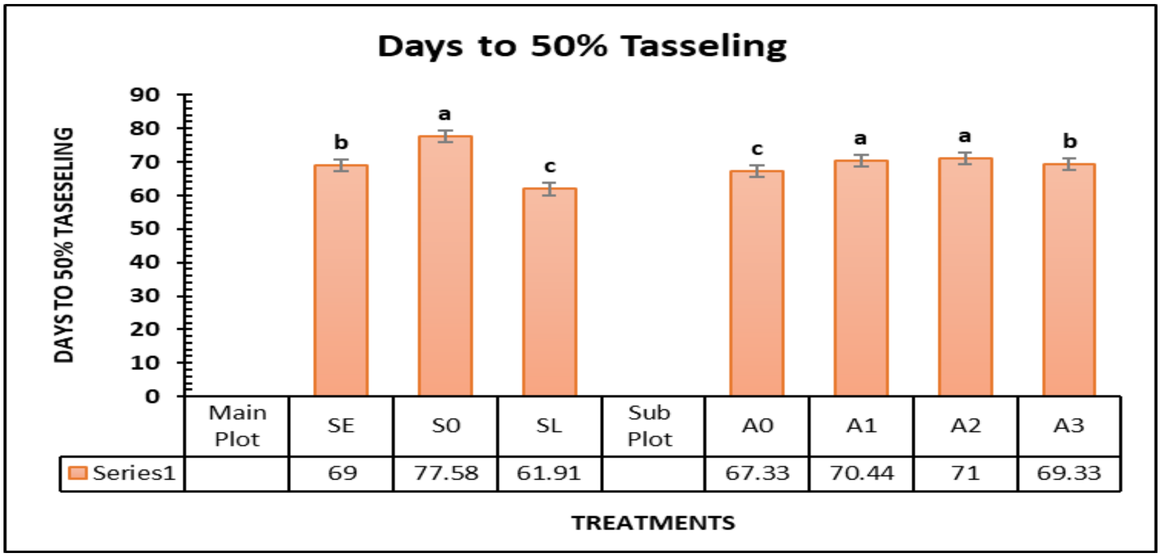
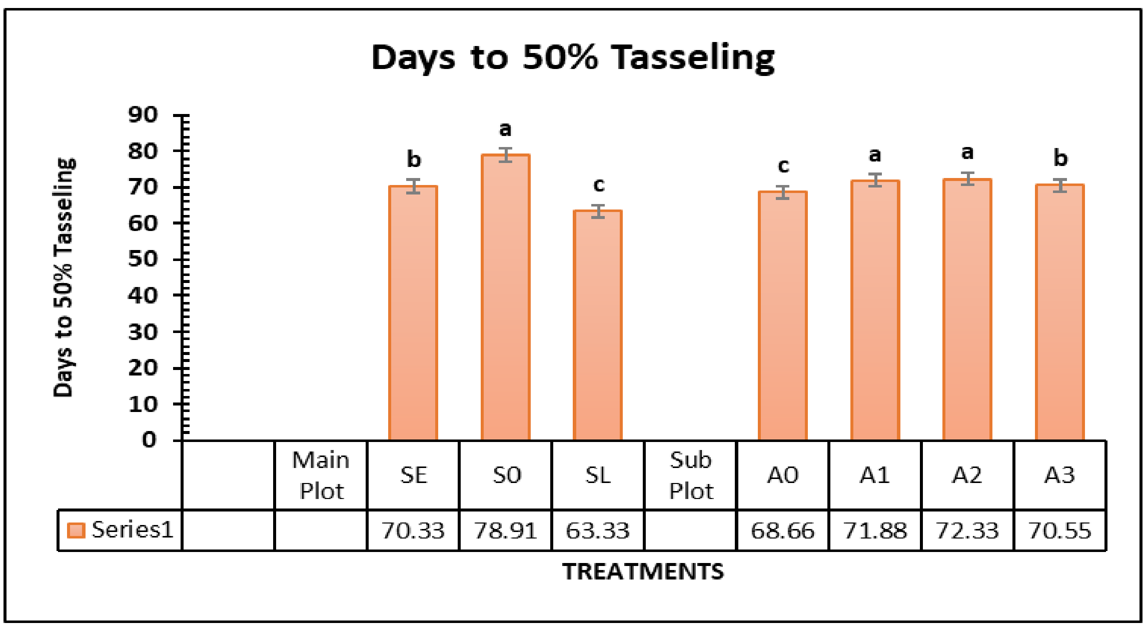


Figure 4.1.8.2b. Effect of sowing dates and agrochemicals treatments on days to 50 % tasseling of maize at 60 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.1.9 Cob Placement Height (cm): The impact of sowing dates and agrochemicals on Cob Placement Height (cm)was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was recorded at 30, 60, and 90 DAS shown in (Table 4.1.9.1, 4.1.9.2 and Figure 4.1.9.1a, 4.1.9.2b). In 2022 and 2023, there was a significant difference in the percentage of Cob Placement Height (cm) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates, and case of agrochemicals, it was estimated by comparing all the standard with control. Thus, the percentage pattern in the Cob Placement Height (cm) was observed at 30, 60, and 90 DAS. It was recorded that in 2022, the percentage of cob placement height was decreased in the case of late sowing (SL) by 0.61%, followed by early sowing (SE) increased by 1.64%, respectively, when compared with the optimum sowing (S0). In the case of applied agrochemicals, A1 showed a better result by decreasing the percentage of cob placement height by 24.42%, followed by A3 and A2 by 22.58% and 15.70%, respectively. The interaction effect of sowing dates and agrochemicals on cob placement height was showed the better result by decreasing the height by SLA3, SEA3, SEA1, SLA2, SOA1, SLA1, S0A2, S0A0, S0A3, SEA0, SEA2, and SLA0 by 54.33, 56.33, 57.33, 59.00, 60.66, 62.66, 64.66, 67.33, 72.33, 75.00, 81.00 and 90.66. In the year 2023, it was found that late sowing (SL) showed a better result by decreasing the percentage by 0.16%, followed by early sowing (SE) by 1.63%, respectively, as compared to the optimum sowing (S0). In the case of applied agrochemicals, it was found that A1 showed a better result by decreasing the percentage by 22.13%, followed by A3 and A2 by 20.95% and 12.05%, respectively, compared to A0. The interaction effect of sowing dates and agrochemicals on cob placement height showed a better result by decreasing the cob placement height in SLA3, SEA3, SEA1, SLA2, S0A1, SLA1, S0A2, S0A2, S0A0, S0A3, SEA0, SEA2, and SLA0 by 56.33, 58.00, 58.60, 6.050, 62.50, 64.33, 66.16, 69.13, 73.93, 76.80, 82.76 and 92.23 respectively. In the complex domain of crop cultivation, the placement height of cobs is crucial in assessing a plant's reaction to external factors that induce stress. This study investigates the intricate dynamics of cob placement height in crops under conditions of untimely sowing, either occurring too early or too late, compared to the recommended planting schedule. Gaining a comprehensive comprehension of the scientific complexities associated with cob development is of utmost importance to elucidate the intricate interactions among environmental factors, the timing of germination, and the subsequent phases of vegetative and reproductive growth. The premature planting of seeds exposes emerging seedlings to a range of environmental stressors that substantially impact the height at which cobs are positioned. Late spring frosts present a significant risk, which has the potential to impede the ideal development and placement of corn cobs. From a scientific standpoint, exposure to cold temperatures has been observed to interfere with crucial physiological processes. These processes include the development of floral primordia and the signaling pathways of hormones, ultimately affecting the synchronized growth of cobs. The repercussions of cold stress are evident in the diminished cob placement height of crops sown early, which has a detrimental effect on the overall reproductive efficacy and subsequent yield capacity. On the other hand, sowing crops later than usual introduces specific environmental stress factors that impact the height at which cobs are positioned. The compressed duration of the growing season exerts considerable pressure on plants to accelerate their reproductive development. From a scientific standpoint, the shortened course may lead to a compromised cob placement height as plants accelerate their growth during the vegetative stage to allocate resources towards reproductive activities. The tangible limitations imposed by time constraints hinder crops' ability to arrange cobs effectively. The complex scientific aspects of this process highlight the importance of maintaining a precise equilibrium in cob placement height during the growth phase, particularly when confronted with diverse environmental stressors that arise from deviating from the suggested timing for sowing (Mehralian et al., 2023; Tolisano and Del Buono 2023; Liu et al., 2023; Feng et al., 2023; Kongala and Kondreddy 2023; Drira et al., 2023; Hussain et al., 2023; Apon et al., 2023). Determining an appropriate sowing timing is of utmost importance in the scientific examination of cob placement height, as it establishes the most favourable conditions for crop growth and reproductive development. The synchronization corresponds to advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which contribute to the effective initiation of floral primordia and the coordinated placement of cobs. From a scientific perspective, this synchronization facilitates the timely initiation of genetic and hormonal mechanisms, resulting in a consistent and optimal positioning of corn cobs at a specific height. The suggested timing establishes the foundation for optimal cob placement height, a crucial factor in the plant's reproductive efficacy and overall yield capacity. To address the potential consequences of environmental stress on cob placement height, a scholarly approach entails investigating the influence of growth regulators. Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate reproductive development in the face of unfavourable circumstances. From a scientific perspective, activating stress response genes by salicylic acid can improve a plant's capacity to endure environmental challenges, which may result in a more coordinated and advantageous placement of cobs. This strategic approach is especially pertinent for crops that are planted early, as it provides a scientific method to enhance the resilience of plants against the potentially harmful impacts of late frosts on their reproductive growth. Furthermore, using sodium nitroprusside as a nitric oxide donor offers a scientific intervention to optimize the height at which cob placement occurs. When sodium nitroprusside is used carefully and deliberately, it impacts important physiological processes essential for reproductive development, including the initiation of floral primordia and hormonal regulation. From a scientific perspective, this application significantly determines the ideal height for placing cobs. It is particularly advantageous for crops sown late and must accelerate their reproductive growth despite a limited growing season. The precise utilization of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from the suggested sowing schedule (Angmo et al., 2024; Yu et al., 2024; Jie Liu et al., 2024; Chen and Zhu 2024; Du et al., 2024; Liu et al., 2024; Boukaew et al., 2024; Silva et al., 2024; He et al., 2024). The investigation of environmental stress on cob placement height in crops from a scientific perspective provides a holistic comprehension of the complex dynamics involving timing, growth conditions, and reproductive maturation. Crops that are sown early face the obstacle of late frosts, which hinder the ideal placement of cobs. On the other hand, crops planted late experience the pressure of a shortened growing season, which affects the positioning of cobs. The determination of the appropriate timing for sowing, based on scientific principles, is crucial in creating favourable conditions for achieving the desired height of cob placement. Incorporating growth regulators, such as salicylic acid and sodium nitroprusside, within the scientific framework provides strategic interventions to improve crops' resilience. These interventions can influence the height at which cobs are positioned and shape the crop's overall reproductive success and yield potential. Investigating reproductive development and environmental stressors in the agricultural domain provides a holistic understanding of the complex mechanisms regulating crop growth stages.

Table 4.1.9.1 Effect of treatments on cob placement height (cm) of maize at DAS during spring season 2022 and 2023

Treatments	Cob placement height (cm) 2022	Cob placement height (cm) 2023
Sowing Date		
SE -Early sowing	67.34	69.04
S0 -Optimum sowing	66.25	67.93
SL -Late sowing	66.66	68.04
Agrochemical		
A0- Control	77.66	79.38
A1-Sodium nitroprusside (250 µM/L)	60.12	61.81
A2-Salicylic acid (150mg/L)	68.22	69.81
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	61.00	62.75
Alpha at 0.05		
CV (Sowing date and agrochemical)	19.88	19.36
CV (Sowing)	18.92	18.59
CD (Agrochemical)	14.31	14.41
CD (Sowing)	13.41	13.12

Table 4.1.9.2 The interaction effect of treatments on cob placement height (cm) of maize at 90 DAS during spring season 2022 and 2023

Treatments	Cob placement height (cm) 2022	Cob placement height (cm) 2023
SEA0	75.00^{abc}±3.61	76.80 ^{abc} ±3.76
SEA1	81.00^{c}±2.65	58.60 ^{c} ±4.49
SEA2	81.00^{ab}±1.05	82.77 ^{ab} ±0.72
SEA3	56.33^{c}±5.51	58.00 ^{c} ±5.68
S0A0	67.33^{abc}±1.53	69.13 ^{abc} ±1.89
S0A1	60.67^{bc}±2.08	62.50 ^{bc} ±1.91
S0A2	64.67^{bc}±2.53	66.17 ^{bc} ±1.53
S0A3	72.33^{abc}±0.53	73.93 ^{abc} ±1.50
SLA0	90.67^{a}±2.1.73	92.23 ^{a} ±2.19
SLA1	62.67^{bc}±1.53	64.33 ^{bc} ±2.02
SLA2	59.00^{bc}±2.52	60.50 ^{bc} ±2.00
SLA3	50.67^{c}±2.89	56.33 ^{c} ±9.50
CV	19.88	19.36
CD	24.17	24.21

Figure 4.1.9.1a. Effect of sowing dates and agrochemicals treatments on cob placement height (cm) of maize at DAS during spring season 2022

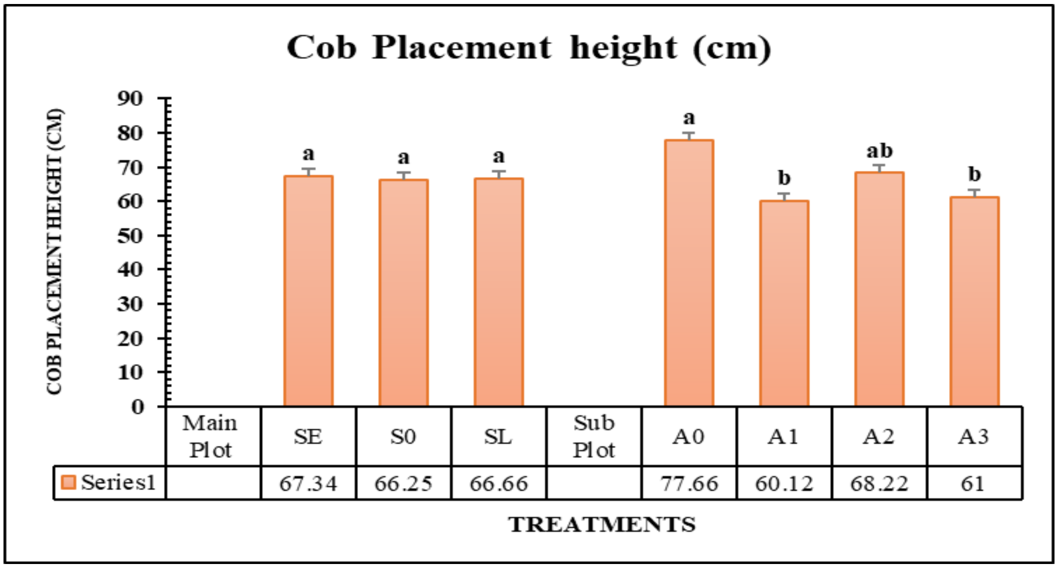
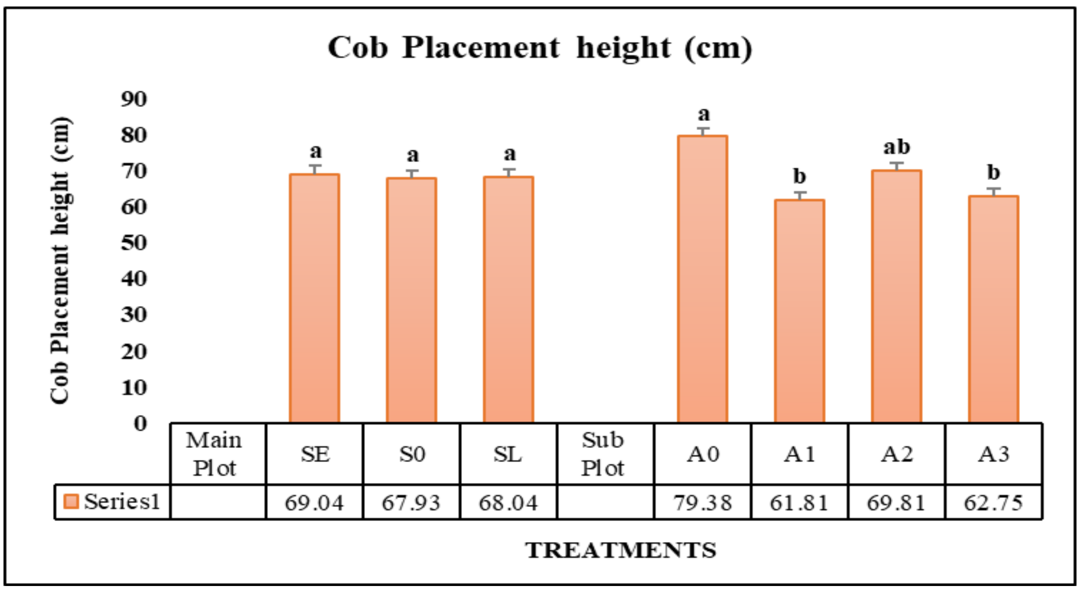


Figure 4.1.9.2b. Effect of sowing dates and agrochemicals treatments on cob placement height (cm) of maize at DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.1.10 Plant Population (plants/m^2): The impact of sowing dates and agrochemicals on Plant Population (plants/1m^2) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was recorded at 60 DAS shown in (Table 4.1.10.1, 4.1.10.2 and Figure 4.1.10.1a,4.1.10.2b). In 2022 and 2023, there was a significant difference in the percentage of Plant Population (plants/m^2) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates, and case of agrochemicals, it was estimated by comparing all the mean with control. Thus, the percentage pattern in the Plant Population (plants/1m^2) was observed at 60 DAS. It was recorded that early sowing (SE) and late sowing (SL) increased the percentage by 3.82% and 5.27%, respectively, when compared to the optimum sowing (S0). In the case of applied agrochemicals, salicylic acid (A2) shows a better result by increasing the percentage by 14.37%, followed by the A1 and A3, i.e.,4.08% and 3.78%, respectively, as compared to the control (A0). The interaction effect of the different sowing and agrochemicals showed better results by increasing the percentage in S0A3<S0A0<S0A1<SEA3<SEA1<SEA0<SLA3<SLA1<SEA2< S0A2<SLA2 by 7.33, 7.33, 7.33, 7.66, 7.66, 7.66, 8.00, 8.00, 8.33, 8.33 and 8.66 respectively. In the year 2023, it was found that late sowing (SL) had the highest percentage, i.e.,4.35%, followed by early sowing (SE) by 3.29% as compared to the optimum sowing (S0). Similarly, applying salicylic acid (A2) increased the parentage by 15.14%, followed by the A1 and A3 compared to the control (A0). The interaction of different sowing and agrochemicals showed better results by increasing the percentage in S0A3<S0A0< S0A1<SEA3<SEA1<SEA0<SLA3<SLA1<SEA2<S0A2<SLA2 by 7.33, 7.33, 7.33, 7.66, 7.66, 7.66, 8.00, 8.00, 8.33, 8.33 and 8.66 respectively. The plant population density is a significant factor within the complex realm of crop cultivation, as it profoundly impacts the growth and productivity of crops. This study examines the intricate dynamics of plant population density in crops when exposed to untimely sowing before or after the recommended planting timeframe. Comprehending the scientific complexities associated with population density is imperative to elucidate the intricate interactions among environmental factors, the timing of germination, and the subsequent phases of vegetative and reproductive development. The premature planting of seeds exposes emerging seedlings to various environmental stressors that substantially influence plant population

density. Late spring frosts present a significant hazard, which has the potential to compromise the viability and survival of juvenile plants. From a scientific perspective, it has been observed that plants exposed to cold temperatures can disrupt crucial physiological processes. These processes include cell division and elongation, which play a significant role in determining the establishment and uniformity of the plant population. The repercussions of cold stress are evident in a diminished and irregular plant density in crops sown early, thereby affecting their structural stability and subsequent growth. On the other hand, delayed sowing of crops introduces specific environmental stress factors that impact the density of plant populations. The compressed duration of the growing season exerts considerable pressure on plants to accelerate their vegetative and reproductive growth. From a scientific standpoint, the shortened timeframe could reduce plant population density as plants expedite their growth stages to allocate resources towards reproductive activities. The ability of crops to effectively manage the arrangement and spacing of plants is hindered by the tangible limitations imposed by time limitations (Aggarwal et al., 2024; Srivastava and Gupta 2024; Aydın 2024; Namatsheve et al., 2024; Muhammad et al., 2024). The scientific complexities of this process highlight the importance of maintaining an optimal plant population density amidst fluctuating environmental stressors that arise from deviations in the suggested sowing schedule. Determining the appropriate timing for sowing emerges as a crucial element in the scientific examination of plant population density, as it establishes the most favourable conditions for the growth of crops. The synchronization corresponds to advantageous environmental factors, such as temperature, soil moisture, and duration of daylight, all of which play a role in facilitating the effective germination, establishment, and consistent growth of plants. From a scientific perspective, this synchronization enables the timely initiation of genetic and hormonal mechanisms, resulting in a uniform and optimal distribution of plants within a population. The suggested timing establishes the foundation for attaining an optimal arrangement and spacing of plants, which are crucial factors influencing the crop's physical strength and overall capacity for production. A scholarly approach entails investigating the influence of growth regulators to alleviate environmental stress's consequences on plant populations' density. Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate plant growth in unfavourable circumstances. From a scientific perspective, salicylic acid's activation of stress response genes has enhanced the plant's capacity to endure environmental challenges. This process can potentially facilitate a more uniform and optimal plant population density. This strategic approach becomes especially pertinent for crops that are sown early, as it provides a scientific method to enhance the resilience of plants against the potential adverse impacts of late frosts on their establishment. In addition, using sodium nitroprusside as a nitric oxide donor offers a scientific intervention to enhance plant population density. When sodium nitroprusside is used carefully and deliberately, it impacts essential physiological processes in plants, including cell division and elongation, which are fundamental to the growth and density of plant populations. From a scientific perspective, this application plays a role in determining the most suitable plant population density (Prado and Barreto 2024; Liu and Moy 2024; Su et al., 2024; Misra and Ghosh 2024). It is particularly advantageous for crops sown late and must accelerate their vegetative and reproductive growth despite a limited growing season. The intricate utilization of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from the suggested sowing schedule. The scientific investigation of the impact of environmental stress on plant population density in crops provides a comprehensive comprehension of the complex interaction between timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops that are sown early face the obstacle of late frosts, which hinder the establishment of an ideal plant population density. On the other hand, crops sown late encounter the challenge of a shortened growing season, which affects the distribution and spacing of plants. Establishing an ideal plant population density is contingent upon adhering to scientifically based principles, with the timing of sowing being a crucial factor. Incorporating growth regulators such as salicylic acid and sodium nitroprusside within the scientific framework provides tactical interventions for augmenting the robustness of crops, exerting influence on plant population density, and shaping the overall structural integrity and yield capacity of the crop. Investigating population density and environmental stressors in the agricultural domain provides a holistic understanding of the complex mechanisms regulating crop development's vegetative and reproductive phases.

Table 4.1.10.1 Effect of treatments on plant population at physiological maturity of maize during spring season 2022 and 2023

Treatments	Plant Population (m^2) 2022	Plant Population (m^2) 2023
Sowing Date		
SE -Early sowing	7.83	7.83
S0 -Optimum sowing	7.58	7.58
SL -Late sowing	7.91	7.91
Agrochemical		
A0- Control	7.33	7.33
A1-Sodium nitroprusside (250 µM/L)	7.66	7.66
A2-Salicylic acid (150mg/L)	8.44	8.44
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	7.66	7.66
Alpha at 0.05		
CV (Sowing date and agrochemical)	16.06	6.06
CV (Sowing)	6.25	6.25
CD (Agrochemical)	0.55	0.92
CD (Sowing)	0.46	0.97

Table 4.1.10.2 The interaction effect of treatments on plant population at physiological maturity (m^2) of maize during spring season 2022 and 2023

Treatments	Plant Population (m^2) 2022	Plant Population (m^2) 2023
SEA0	7.67^{bcd}±0.58	7.67^{bcd}±0.58
SEA1	7.67^{bcd}±0.58	7.67^{bcd}±0.58
SEA2	8.33^{ab}±0.58	8.33^{ab}±0.58
SEA3	7.67^{bcd}±0.58	7.67^{bcd}±0.58
S0A0	7.33^{cd}±0.58	7.33^{cd}±0.58
S0A1	7.33^{cd}±0.58	7.33^{cd}±0.58
S0A2	8.33^{ab}±0.58	8.33^{ab}±0.58
S0A3	7.33^{cd}±0.58	7.33^{cd}±0.58
SLA0	7.33^{d}±0.58	7.33^{d}±0.58
SLA1	7.67^{abc}±0.58	7.67^{abc}±0.58
SLA2	8.67^{a}±0.58	8.67^{a}±0.58
SLA3	7.67^{abc}±0.58	7.67^{abc}±0.58
CV	16.06	6.06
CD	0.88	1.72

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.1.10.1a. Effect of sowing dates and agrochemicals treatments on plant population at physiological maturity of maize during spring season 2022

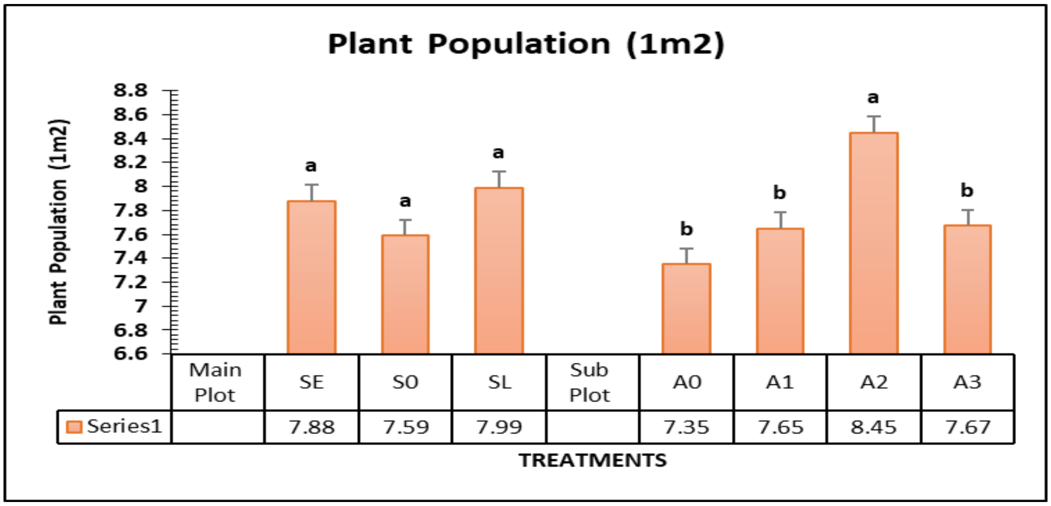
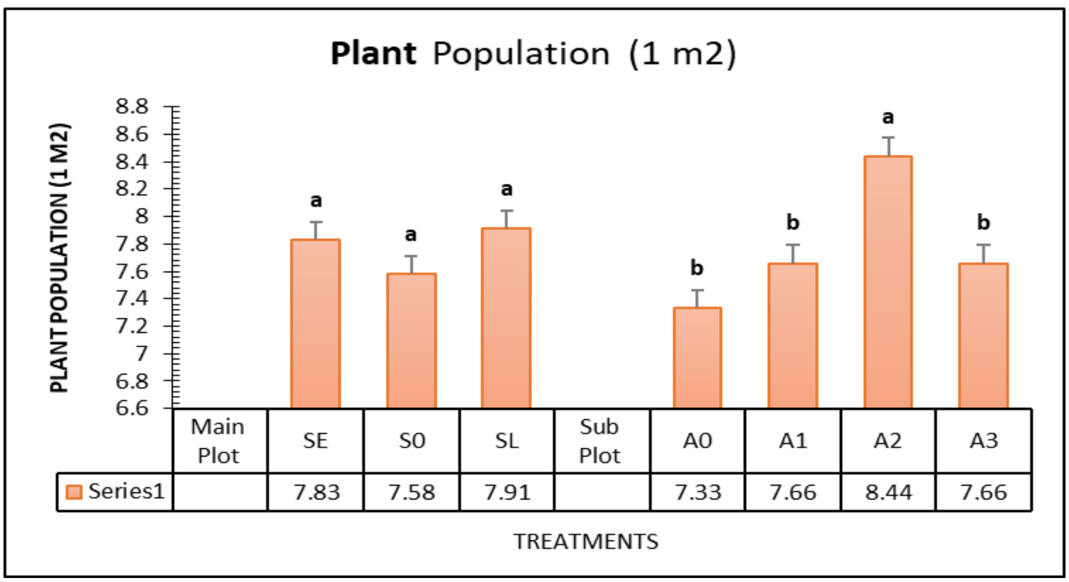


Figure 4.1.10.2b. Effect of sowing dates and agrochemicals treatments on plant population at physiological maturity of maize during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.1.11 Crop Growth Rate (g/cm^2/day): The impact of sowing dates and agrochemicals on Crop Growth Rate (g/cm^2/day) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS shown in (Table 4.1.11.1, 4.1.11.2 and Figure 4.1.11.1a,4.1.11.2b). In 2022 and 2023, there was a significant difference in the percentage of Crop Growth Rate (g/cm^2/day) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals it was calculated by comparing all the mean with control. Thus, the percentage pattern in Crop Growth Rate (g/cm^2/day) was observed at 30, 60 and 90 DAS. It was recorded that in 2022, late sowing (SL) showed better and increased the percentage by 37.14% compared to early sowing (SE) at 30 DAS. At 60 DAS, late sowing (SL) and early sowing (SE) increased the percentage by 38.37% and 22.09%, respectively, as compared to the optimum sowing (S0). In the case of 90 DAS, the late sowing (SL) showed a better result by increasing the percentage by 3.64%, whereas in early sowing (SE), it was decreased by 60.21% when compared with the optimum sowing (S0). Similarly, in the case of applied agrochemicals, the salicylic acid (A2) had the highest percentage, i.e. 6.18%, 35.63%, and 12.8 at 30, 60, and 90 DAS, respectively when it was compared to the control (A0). The combined application showed a better result (A3) and increased the percentage by 2.12%, 16.78%, and 8.65%, respectively, compared to the control (A0), and similar trends were followed at 90 DAS. In the year 2023, it was found that the percentage was significantly decreased more in the case of early sowing (SE) at 66.66%, and in late sowing, it decreased by 36.11%, respectively, as compared to the optimum sowing (S0) at 30 DAS. At 60 DAS, late sowing (SL) and early sowing increased the percentage by 37.07% and 21.34%, respectively, compared to the optimum sowing (S0). But, in the case of 90 DAS, early sowing decreased the percentage by 60.21%, and late sowing increased the percentage by 3.64% compared to the optimum sowing (S0). Among the applied agrochemicals, the application of salicylic acid showed a better result. It increased the percentage by 6.51%, 28.44%, and 18.33% at 30, 60 and 90 DAS, respectively, followed by the A3 and A2 compared to the control (A0). Within the complex domain of crop cultivation, the rate at which crops grow is a crucial metric for evaluating a plant's reaction to various environmental stressors. This study investigates the intricate dynamics of crop growth rate under conditions of untimely sowing, either in advance or delayed, compared to the prescribed planting timetable. Comprehending the scientific complexities associated with growth rate is imperative to elucidate the intricate interactions among environmental factors, the timing of germination, and the subsequent phases of vegetative and reproductive growth. The premature planting of seeds exposes emerging seedlings to various environmental stressors, which substantially affect the growth rate of crops. Late spring frost events present a significant risk, potentially hindering the ideal commencement of growth processes. From a scientific perspective, it has been observed that being exposed to cold temperatures can have a disruptive effect on crucial physiological processes. These processes include cell division and elongation, impacting crop growth's overall rate and consistency. The repercussions of cold stress are evident in the decelerated and irregular growth rate observed in crops sown early, affecting their structural integrity and subsequent development. On the other hand, delayed sowing introduces specific environmental stress factors that impact the crop growth rate. The compressed duration of the growing season exerts substantial pressure on plants to accelerate their vegetative and reproductive development. From a scientific standpoint, the shortened course may lead to a compromised growth rate as plants expedite their progression through various stages to allocate resources towards reproductive activities (Singh et al., 2024; Wang et al., 2024; Wang et al., 2024; Loaiza et al., 2024; Chen et al., 2024; Su et al., 2024). The tangible limitations imposed by temporal constraints hinder crops' ability to maximize their growth rate. The scientific complexities of this process highlight the need for a careful equilibrium to attain an optimal growth rate amidst the diverse environmental pressures that arise from deviating from the suggested timing for sowing. The timing of sowing is a crucial element in the scientific study of crop growth rate, as it determines the ideal conditions for the growth and development of crops. The synchronization corresponds to advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which contribute to the proficient initiation of growth and consistent development of plants. From a scientific perspective, synchronization facilitates the timely initiation of genetic and hormonal mechanisms, resulting in a consistent and optimal crop growth rate. The suggested timing establishes the foundation for attaining an optimal rate of development, a crucial factor in determining the crop's structural soundness and overall capacity for production. To address the adverse effects of environmental stress on the rate of crop growth, a scientific methodology entails investigating the potential influence of growth regulators. Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate growth in the face of unfavorable circumstances. From a scientific perspective, salicylic acid's activation of stress response genes has been observed to improve the plant's capacity to endure environmental challenges, thereby facilitating a more consistent and optimal crop growth rate. This strategic approach is especially pertinent for crops that are planted early, as it provides a scientific method to enhance the resilience of plants against the potentially adverse impacts of late frosts on their growth processes. In addition, sodium nitroprusside, which acts as a donor of nitric oxide, offers a scientific intervention to maximise crop growth. When used carefully and deliberately, sodium nitroprusside impacts essential physiological processes, including cell division and elongation, which are fundamental to the growth rate. From a scientific perspective, this application plays a significant role in facilitating the attainment of an ideal growth rate. It is particularly advantageous for crops sown late and facing the challenge of achieving vegetative and reproductive growth within a limited growing season (Zhan et al., 2024; Kozeko et al., 2024; Hefft and Adetunji 2024; Baruah et al., 2024; Karthika 2024). The intricate utilisation of these growth regulators underscores their capacity to regulate the physiological reactions of crops when confronted with environmental stressors that arise from deviations in the recommended sowing schedule. The scientific investigation of the impact of environmental stress on the crop growth rate provides a thorough comprehension of the complex dynamics involving timing, growth conditions, and vegetative and reproductive development. Crops are sown early to face the obstacle of late frosts, which hinders their ability to grow optimally. On the other hand, crops planted late experience the challenge of a condensed growing season, which affects the rate at which they can grow. The timing of sowing, based on scientific principles, is a crucial factor in creating favourable conditions for achieving an optimal crop growth rate. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into the scientific methodology provides strategic interventions for augmenting the resilience of crops.

Table 4.1.11.1 Effect of treatments on Crop Growth Rate (g/cm^2/day) of Maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Crop Growth Rate-2022			Crop Growth Rate-2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	0.22	1.05	1.09	0.24	1.08	1.09
S0 -Optimum sowing	0.70	0.86	2.74	0.72	0.89	2.74
SL -Late sowing	0.44	1.19	2.84	0.46	1.22	2.84
(Agrochemicals)						
A0- Control	0.44	1.06	1.02	0.46	1.09	1.02
A1-Sodium nitroprusside (250 µM/L)	0.44	0.87	1.45	0.46	0.90	1.45
A2-Salicylic acid (150mg/L)	0.47	1.37	2.89	0.49	1.40	2.89
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	0.45	0.83	3.52	0.47	0.86	3.53
CV (Sowing)	5.04	18.96	47.89	4.83	18.43	47.87
CV (Sowing date and agrochemical)	4.23	17.88	57.82	4.05	17.38	57.79
CD (Sowing)	0.02	0.22	1.20	0.03	0.21	1.21
CD (Agrochemicals)	0.01	0.18	1.27	0.02	0.17	1.25

Table 4.1.11.2 The interaction effect of treatments on Crop Growth Rate (g/cm^2/day) of Maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Crop Growth Rate-2022			Crop Growth Rate-2023		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
SEA0	0.17^{h}±0.01	1.08^{bc}±0.02	0.59^{e}±0.22	0.19^{h}±0.01	1.11^{bc}±0.02	0.59^{e}±0.22
SEA1	0.19^{gh}±.0.01	1.05^{bc}±0.03	0.85^{e}±0.34	0.21^{gh}±0.01	1.08^{bc}±0.03	0.85^{e}±0.34
SEA2	0.21^{g}±0.00	1.17^{bc}±0.06	1.81^{cde}±0.35	0.23^{g}±0.00	1.20^{bc}±0.06	1.81^{cde}±0.35
SEA3	0.33^{f}±0.01	0.93^{bcde}±0.03	1.13^{de}±0.72	0.35^{f}±0.01	0.96^{bcde}±0.03	1.13^{de}±0.72
S0A0	0.70^{b}±0.01	0.87^{cde}±0.02	1.82^{cde}±0.60	0.72^{b}±0.01	0.90^{cde}±0.02	1.83^{cde}±0.60
S0A1	0.70^{b}±0.01	0.61^{e}±0.03	0.98^{e}±0.47	0.72^{b}±0.01	0.64^{e}±0.03	0.98^{e}±0.47
S0A2	0.83^{a}±0.04	1.28^{b}±0.07	3.62^{abc}±3.23	0.85^{a}±0.04	1.31^{b}±0.07	3.62^{abc}±3.23
S0A3	0.58^{c}±0.01	0.70^{de}±0.07	4.54^{ab}±1.71	0.60^{c}±0.01	0.73^{de}±0.07	4.54^{ab}±1.71
SLA0	0.39^{d}±0.14	1.26^{b}±0.04	0.66^{e}±0.36	0.48^{d}±0.03	1.29^{b}±0.04	0.66^{e}±0.36
SLA1	0.46^{d}±0.02	0.97^{bcd}±0.12	2.54^{bcde}±0.66	0.48^{d}±0.02	1.00^{bcd}±0.12	2.54^{bcde}±0.66
SLA2	0.39^{e}±0.02	1.69^{a}±0.63	3.26^{abcd}±1.03	0.41^{e}±0.02	1.72^{a}±0.63	3.26^{abcd}±1.03
SLA3	0.47^{f}±0.03	0.88^{cde}±0.06	4.92^{a}±2.94	0.49^{d}±0.03	0.91^{cde}±0.06	4.92^{a}±2.94
CV	4.23	17.88	57.82	4.05	17.38	57.79
CD	0.03	0.35	2.24	0.04	0.36	2.25

Figure 4.1.11.1a. Effect of sowing dates and agrochemicals treatments on Crop Growth Rate (g/cm^2/day) of Maize at 30, 60, and 90 DAS during spring season 2022

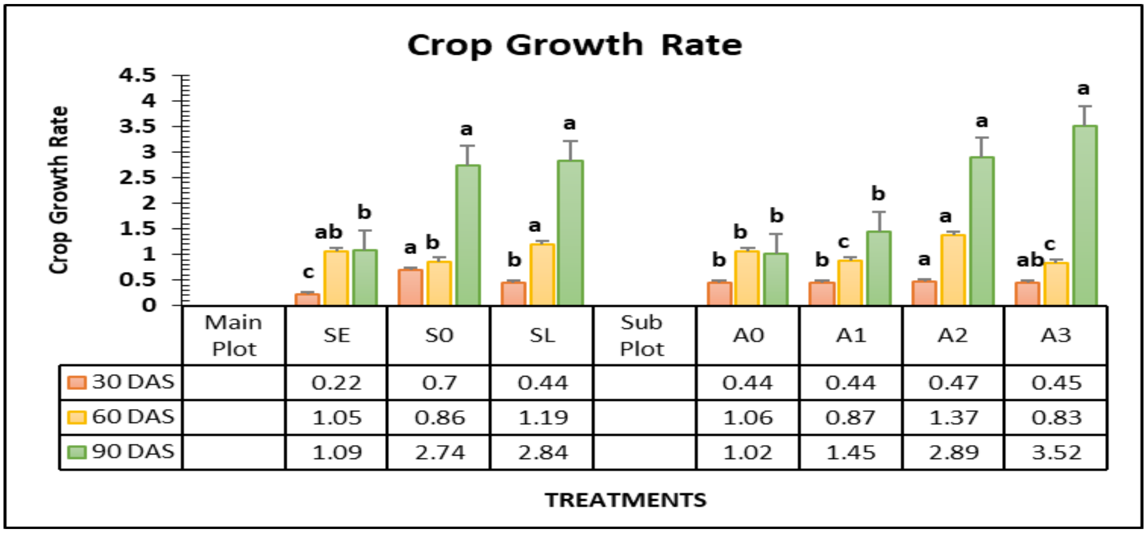
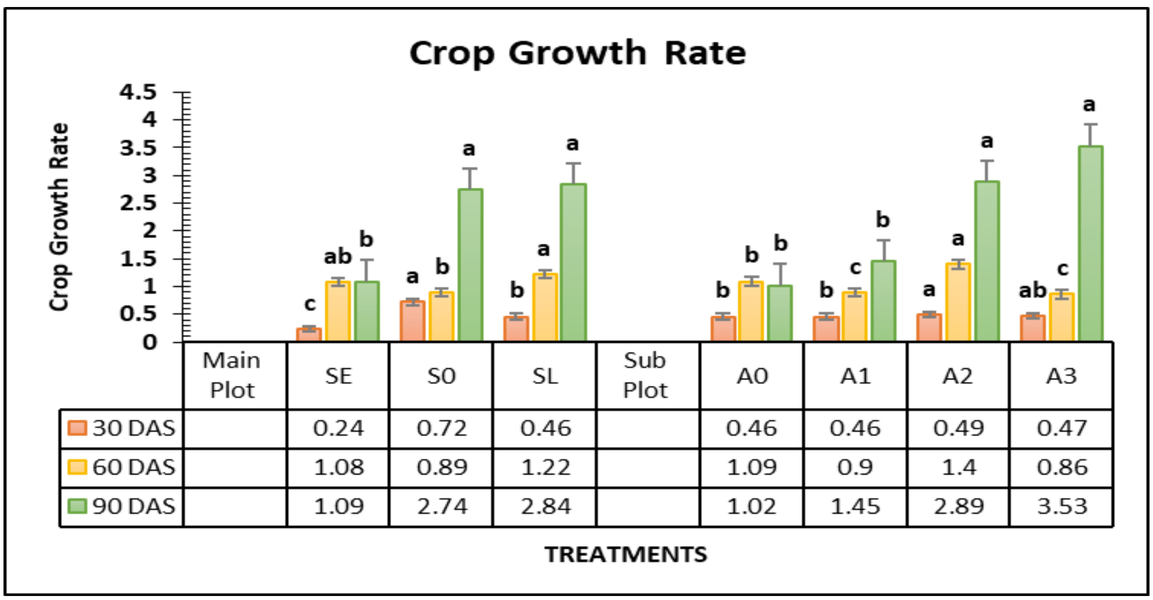


Figure 4.1.11.2b. Effect of sowing dates and agrochemicals treatments on Crop Growth Rate (g/cm^2/day) of Maize at 30, 60, and 90 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.1.12 Relative Growth Rate (g/g/day): The impact of sowing dates and agrochemicals on Relative Growth Rate (g/g/day) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS shown in (Table 4.1.12.1, 4.1.12.2 and Figure 4.1.12.1a, 4.1.12.2b). In 2022 and 2023 there was a significant difference in the percentage of Relative Growth Rate (g/g/day) sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals; it was calculated by comparing all the mean with control. Thus, the percentage pattern in Relative Growth Rate (g/g/day) was observed at 30, 60 and 90 DAS. In 2022, early sowing decreased the percentage by 17.64%, and late sowing decreased by 52.94%, respectively, compared to optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing (SE) decreased by 15.0% and late sowing (SL) by 10.12%, respectively, as compared to the optimum sowing (S0). In the case of 90 DAS, the early sowing (SE) decreased by 36.66% compared to the optimum sowing (S0). Salicylic acid (A2) application in applied agrochemicals shows better results by increasing the percentage by 10.25% and 59.09% at 60 and 90 DAS, respectively, compared to control (A0). At 90 DAS, the combined application of salicylic acid and sodium nitroprusside (A3) had the highest percentage of relative growth rate, i.e. 79.31%, followed by A2 and A2 by 59.09% and 37.5%, respectively, when compared with control (A0). In 2023, the early sowing decreased the percentage by 7.69% and late sowing (SL) by 21.05% compared to the optimum sowing (A0) at 30 DAS. At 60 DAS, late sowing (SL) increased the percentage by 66.66% and early showing (SE) by 16.98% as compared to the optimum sowing (S0). Similarly, at 90 DAS, the late sowing (SL) decreased the percentage by 0.24% and the early sowing by 36.52% compared to the optimum sowing (S0). In the case of applied agrochemicals, the application of salicylic acid showed a better result by increasing the percentage of relative growth rate by 7.40% and 50.00% at 60 and 90 DAS, respectively, compared to the control (A0). At 90 DAS, the combined application of agrochemicals (A3) showed the highest percentage, i.e., 88.46%, followed by A2 and A3, i.e. 50.65% and 23.07%, respectively. Within the complex domain of crop cultivation, the relative growth rate (RGR) assumes a crucial role as a metric for evaluating a plant's reaction to environmental stressors. This study examines the intricate dynamics of relative growth rate (RGR) in crops when exposed to untimely sowing before or after the recommended planting timeframe. Comprehending the scientific intricacies of close growth rate (RGR) is imperative to decipher the intricate interplay among environmental factors, timing of germination, and the subsequent phases of vegetative and reproductive growth (Wang et al., 2024; Pandey et al., 2024c; Yang et al., 2024; Jiang et al., 2024). When seeds are sown before the optimal time, the resulting seedlings are exposed to various environmental stressors that substantially affect their Relative Growth Rate (RGR). Late spring frosts present a significant risk, potentially hindering the ideal commencement of growth processes. From a scientific standpoint, exposure to cold temperatures has been observed to interfere with crucial physiological processes, such as cell division and elongation. This interference directly impacts the overall rate and consistency of the Relative Growth Rate (RGR). The effects of cold stress are observed in early-sown crops as a reduction in relative growth rate and an irregular growth pattern, leading to compromised structural integrity and hindered subsequent development. On the other hand, delayed sowing of crops introduces specific environmental stress factors that impact the Relative Growth Rate (RGR). The compressed duration of the growing season exerts substantial pressure on plants to accelerate their vegetative and reproductive growth. From a scientific standpoint, the shortened time frame could lead to a diminished relative growth rate (RGR) as plants expedite their progression through various stages to allocate resources towards reproductive activities. The ability of crops to maximize their relative growth rate (RGR) is hindered by the tangible limitations imposed by temporal constraints. The scientific complexities of this process highlight the importance of maintaining a precise equilibrium to attain an optimal relative growth rate (RGR) amidst diverse environmental stressors resulting from deviations from the suggested timing for sowing. Determining the appropriate timing for sowing is a crucial aspect in the scientific examination of relative growth rate (RGR), as it establishes the most favourable circumstances for the growth and development of crops. The synchronization of timing corresponds to advantageous environmental factors, such as temperature, soil moisture, and duration of daylight, all of which promote effective germination and consistent relative growth rate (RGR). From a scientific perspective, the synchronization facilitates the timely initiation of genetic and hormonal mechanisms, resulting in a consistent and optimal Relative Growth Rate (RGR). The suggested timing establishes the foundation for attaining an optimal Root Growth

Ratio (RGR) rate, a crucial factor in determining the crop's structural soundness and overall yield potential. To address the consequences of environmental stress on relative growth rate (RGR), a scholarly approach entails investigating the influence of growth regulators (Gupta et al., 2024; Stelluti et al., 2024; Wolkis and Maunder 2024). Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate growth in the face of unfavourable circumstances. From a scientific perspective, salicylic acid's activation of stress response genes has been observed to improve a plant's capacity to endure environmental challenges. This process can facilitate a more consistent and optimal relative growth rate (RGR). This strategic approach is especially pertinent for crops that are planted early, as it provides a scientific method to enhance the resilience of plants against the potentially adverse impacts of late frosts on their growth processes. In addition, using sodium nitroprusside as a nitric oxide donor offers a scientific intervention to optimize relative growth rate (RGR). When sodium nitroprusside is used carefully and deliberately, it impacts important physiological processes, including cell division and elongation, which are fundamental to relative growth rate (RGR). From a scientific perspective, this application plays a role in developing an ideal Relative Growth Rate (RGR), which is especially advantageous for crops planted late and needs to accelerate both vegetative and reproductive growth despite having a limited growing season. The intricate utilization of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from the suggested sowing schedule. The scientific investigation of the impact of environmental stress on relative growth rate (RGR) in crops provides a holistic comprehension of the complex dynamics involving timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops are sown early to face the obstacle of late frosts, which hinder their ability to achieve an optimal Relative Growth Rate (RGR). On the other hand, crops that are sown late encounter the challenge of a condensed growing season, which affects the rate at which they can achieve their RGR. Establishing optimal conditions for achieving an ideal relative growth rate (RGR) is contingent upon adhering to scientifically-derived principles regarding the timing of sowing. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into the scientific methodology provides strategic interventions for improving the resilience of crops. These interventions can influence the relative growth rate (RGR) and contribute to the crop's overall structural integrity and yield potential. Investigating RGR (Relative Growth Rate) and environmental stressors in various fields contributes to a holistic understanding of the complex mechanisms that regulate crop development's vegetative and reproductive phases (Schasteen 2024; Kaushik et al., 2024; Jampílek and Kráľová 2024; Costa et al., 2024).

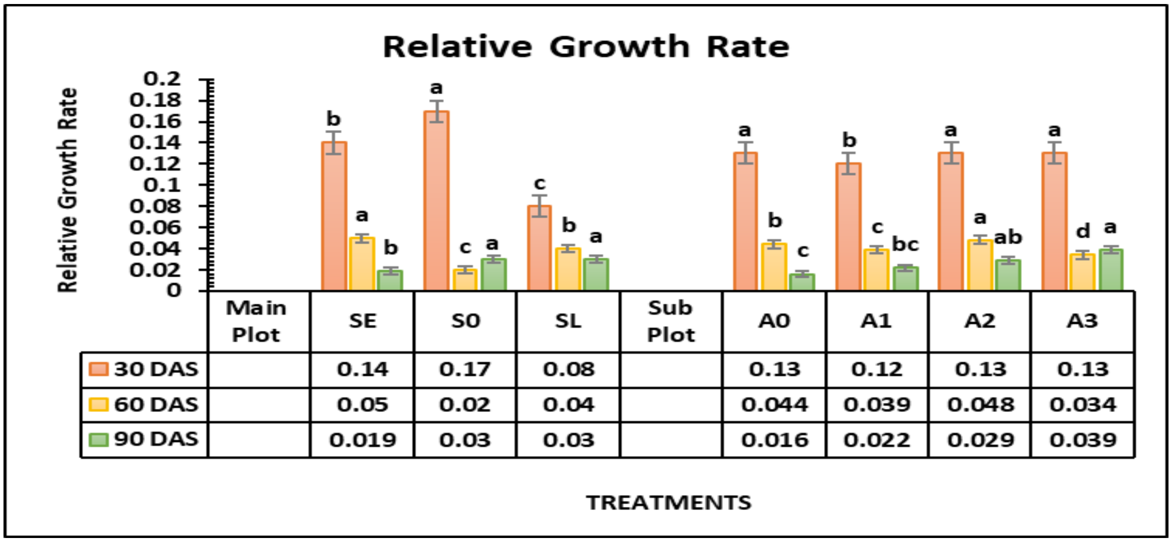
Table 4.1.12.1 Effect of treatments on Relative Growth Rate (g/g/day) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Relative Growth Rate-2022			Relative Growth Rate-2023		
At different Interval	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
(Sowing Date)						
SE -Early sowing	0.14	0.05	0.019	0.16	0.06	0.0259
S0 -Optimum sowing	0.17	0.02	0.030	0.19	0.03	0.0408
SL -Late sowing	0.08	0.04	0.030	0.10	0.05	0.0407
(Agrochemicals)						
A0- Control	0.13	0.044	0.016	0.15	0.054	0.026
A1-Sodium nitroprusside (250 µM/L)	0.12	0.039	0.022	0.14	0.04	0.032
A2-Salicylic acid (150mg/L)	0.13	0.048	0.029	0.15	0.058	0.039
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	0.13	0.034	0.039	0.15	0.04	0.049
CV (Sowing)	5.40	7.47	16.75	4.62	6.03	12.22
CV (Sowing date and agrochemical)	7.04	8.06	35.40	6.12	6.51	25.84
CD (Sowing)	0.08	0.003	0.005	0.008	0.002	0.005
CD (Agrochemicals)	0.09	0.002	0.009	0.092	0.003	0.008

Table 4.1.12.2 The interaction effect of treatments on Relative Growth Rate (g/g/day) of Maize at 30, 60, and 90 DAS during spring season 2022 and 2023

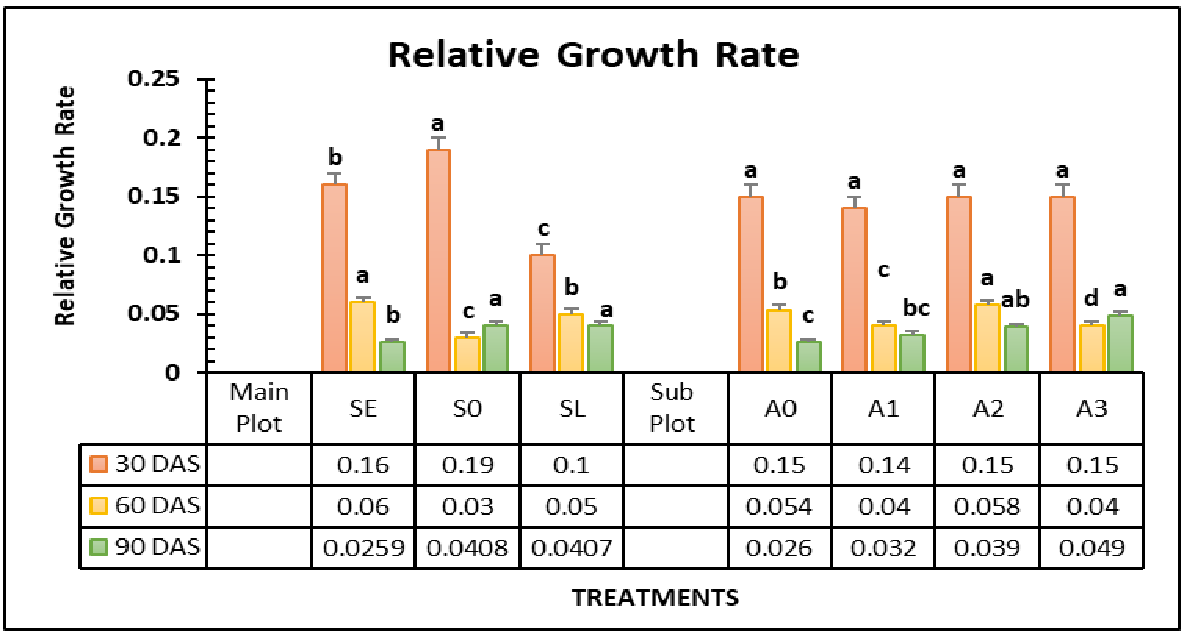
Treatments	Relative Growth Rate-2022			Relative Growth Rate-2023		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
SEA0	0.13^{c}±0.02	0.07^{a}±0.00	0.01^{ef}±0.00	0.16^{bc}±0.01	0.08^{a}±0.00	0.02^{ef}±0.00
SEA1	0.14^{bc}±0.01	0.08^{a}±0.02	0.02^{def}±0.01	0.15^{c}±0.01	0.08^{a}±0.01	0.03^{def}±0.01
SEA2	0.15^{c}±0.04	0.09^{a}±0.03	0.03^{cde}±0.00	0.15^{c}±0.06	0.09^{a}±0.01	0.04^{cde}±0.00
SEA3	0.14^{bc}±0.00	0.04^{c}±0.00	0.02^{cdef}±0.01	0.11^{bc}±0.00	0.05^{c}±0.00	0.03^{cdef}±0.01
S0A0	0.18^{a}±0.02	0.03^{f}±0.00	0.03^{cdef}±0.01	0.20^{a}±0.02	0.04^{f}±0.01	0.04^{cdef}±0.01
S0A1	0.16^{b}±0.00	0.02^{g}±0.00	0.02^{cdef}±0.01	0.18^{b}±0.00	0.03^{g}±0.00	0.03^{cdef}±0.01
S0A2	0.19^{a}±0.01	0.05^{ef}±0.03	0.05^{cd}±0.04	0.21^{a}±0.01	0.05^{ef}±0.02	0.04^{cd}±0.02
S0A3	0.16^{b}±0.01	0.03^{fg}±0.00	0.05^{a}±0.01	0.18^{b}±0.01	0.04^{fg}±0.00	0.06^{a}±0.01
SLA0	0.08e±0.01	0.04^{cd}±0.00	0.01^{f}±0.00	0.10^{e}±0.01	0.05^{cd}±0.00	0.02^{f}±0.01
SLA1	0.09^{de}±0.00	0.04^{de}±0.00	0.03^{bc}±0.01	0.11^{de}±0.00	0.05^{de}±0.00	0.04^{bc}±0.00
SLA2	0.08^{de}±0.00	0.05^{b}±0.01	0.05^{bcd}±0.044	0.14^{de}±0.06	0.06^{b}±0.01	0.04^{bcd}±0.01
SLA3	0.10^{d}±0.01	0.03^{e}±0.00	0.05^{ab}±0.02	0.12^{d}±0.01	0.04^{e}±0.00	0.06^{a}±0.02
CV	7.04	8.06	35.40	6.12	6.51	25.84
CD	0.01	0.006	0.015	0.015	0.006	0.016

Figure 4.1.12.1a. Effect of sowing dates and agrochemicals treatments on Relative Growth Rate (g/g/day) of maize at 30, 60, and 90 DAS during spring season 2022



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		0.14	0.17	0.08		0.13	0.12	0.13	0.13
60 DAS		0.05	0.02	0.04		0.044	0.039	0.048	0.034
90 DAS		0.019	0.03	0.03		0.016	0.022	0.029	0.039

Figure 4.1.12.2b. Effect of sowing dates and agrochemicals treatments on Relative Growth Rate (g/g/day) of maize at 30, 60, and 90 DAS during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		0.16	0.19	0.1		0.15	0.14	0.15	0.15
60 DAS		0.06	0.03	0.05		0.054	0.04	0.058	0.04
90 DAS		0.0259	0.0408	0.0407		0.026	0.032	0.039	0.049

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.1.13 Net Assimilation Rate (mg/cm^2/day): The impact of sowing dates and agrochemicals on the Net Assimilation Rate (mg/cm^2/day) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS shown in (Table 4.1.13.1, 4.1.13.2 and Figure 4.1.13.1a,4.1.13.2b). In 2022 and 2023, there was a significant difference in the percentage of Net Assimilation Rate (mg/cm^2/day) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standard with the control. Thus, the percentage pattern in Net Assimilation Rate (mg/cm^2/day) was observed at 30, 60, and 90 DAS. In 2022, it was recorded that late sowing decreased the percentage by 20.99% and early sowing (SE) by 42.70% compared to the optimum sowing (S0) at 30 DAS. Similarly, at 60 and 90 DAS, the early sowing (SE) decreased the percentage by 73.01% and 56.89%, followed by late sowing (SL) by 17.89 % and 19.45%, respectively, when compared with optimum sowing (S0). In the case of applied agrochemicals, the combined application showed a better result and had less decrease in percentage, i.e. 16.03%, followed by A2 and A1, respectively, at 30 DAS. At 60 DAS, the sodium nitroprusside showed a reduction in percentage by 37.67% followed by late sowing (SL) by 31.50%, respectively, when compared with optimum sowing (S0). At 90 DAS, salicylic acid (A2) application showed a better result by increasing the percentage by 8.79%, followed by A3 and A1, respectively. In the year 2023, it was recorded that late sowing (SE) decreased by 20.99% and late sowing (SL) by 42.70% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, the late sowing (SL) increased the percentage by 33.33% and early sowing (SE) by 12.67% as compared to optimum sowing (S0). In the case of 90 DAS, early sowing (SE) was increased by 9.93% and Late sowing (SL) by 26.13%, respectively, compared to optimum sowing. It was found that the application of salicylic acid (A2) in agrochemicals showed the highest percentage increase by 1.82% and 1.48% at 60 and 90 DAS, respectively when it was compared to the control (A0). It was also recorded that the combined applications showed better results by increasing the percentage by 8.67% and 7.95% at 60 and 90 DAS, respectively, compared with the control (A0). Within the complex field of crop physiology, the Net Assimilation Rate (NAR) is a critical parameter for evaluating a plant's reaction to various environmental stressors. This study examines the intricate mechanisms of nonadditive response (NAR) in crops when exposed to untimely sowing, either in advance or delayed, compared to the prescribed planting timetable. Comprehending the scientific intricacies of NAR (Non-Accidental Reseeding) is imperative to decipher the intricate interplay among environmental factors, timing of germination, and the subsequent phases of vegetative and reproductive growth. When seeds are planted before the optimal time, the resulting seedlings are exposed to various environmental stressors that significantly impact their net assimilation rate (NAR). Late spring frosts present a considerable risk, potentially hindering the ideal commencement of physiological processes. From a scientific perspective, exposure to cold temperatures has been observed to interfere with crucial metabolic pathways, such as photosynthesis and carbon assimilation, thereby impacting the overall rate and effectiveness of the net assimilation rate (NAR). The effects of cold stress are evident in the reduced and irregular net assimilation rate (NAR) observed in crops sown early, leading to a decrease in biomass accumulation and subsequent growth. On the other hand, delayed sowing of crops introduces specific environmental stressors that impact the net assimilation rate (NAR). The compressed duration of the growing season exerts considerable pressure on plants to accelerate their vegetative and reproductive growth. From a scientific standpoint, the shortened time frame may lead to a diminished net assimilation rate (NAR) as plants expedite their progression through various stages to allocate resources towards reproductive endeavours. The ability of crops to maximise their net assimilation rate (NAR) is hindered by the tangible limitations imposed by time constraints. The scientific complexities of this process highlight the need for a careful equilibrium to attain an optimal NAR amidst the diverse environmental stressors resulting from a departure from the suggested timing for sowing. Determining the appropriate timing for sowing is of utmost importance in the scientific examination of NAR, as it establishes the most favourable circumstances for the growth and progression of crops (Godínez-Mendoza et al., 2023; Sharma et al., 2023; Hidangmayum et al., 2023; Kumar and Yati 2002; Wu and Li 2022; Kotia et al., 2021; Kumar and Naik 2020; Dwivedi and Kumar 2011; Pathak et al., 2017; Srivastav et al., 2023). The synchronisation corresponds with advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which contribute to effective photosynthesis and a stable net assimilation rate. From a scientific perspective, the synchronisation facilitates the timely initiation of metabolic processes, resulting in a consistent and optimal Net Assimilation Rate (NAR). The suggested timing establishes the foundation for attaining an optimal net assimilation rate (NAR) rate, a crucial factor in the crop's biomass generation and overall yield capacity. A scholarly approach entails investigating the influence of growth regulators to address the adverse effects of environmental stress on NAR (nutrient assimilation rate). Salicylic acid, renowned for its participation in plant defence mechanisms, can be deliberately administered to regulate metabolic processes in the face of unfavourable circumstances. From a scientific perspective, salicylic acid's activation of stress response genes has improved a plant's capacity to endure environmental stresses. This may contribute to a more consistent and optimal net assimilation rate (NAR). This strategic approach is especially pertinent for crops that are planted early, as it provides a scientific method to enhance the resilience of plants against the potential adverse impacts of late frosts on their metabolic processes. Using sodium nitroprusside as a nitric oxide donor offers a scientific intervention for optimising NAR. The judicious application of sodium nitroprusside significantly impacts important physiological processes, including carbon assimilation and photosynthetic efficiency, which are fundamental to the nitrogen assimilation rate (NAR). From a scientific perspective, this application plays a role in developing an ideal NAR (Net Assimilation Rate), which is especially advantageous for crops sown late and needs to enhance both vegetative and reproductive growth despite a limited growing season. The intricate utilisation of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronted with environmental stressors linked to deviations from the suggested sowing schedule. Investigating environmental stress on non-structural carbohydrate allocation in crops thoroughly comprehends the complex dynamics involving timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops that are sown early face the obstacle of late frosts, which hinder the achievement of optimal Net Assimilation Rate (NAR). On the other hand, crops that are sown late encounter the challenge of a shortened growing season, which affects the rate at which NAR occurs. Based on scientific principles, determining the appropriate timing for sowing is crucial in creating favourable conditions for attaining an optimal Net Assimilation Rate (NAR). Incorporating growth regulators such as salicylic acid and sodium nitroprusside within the scientific framework provides strategic interventions to improve crops' resilience. These interventions can impact the net assimilation rate (NAR) and influence the overall accumulation of biomass and crop yield potential. The ongoing scientific exploration in various disciplines has contributed to a deeper understanding of the relationship between NAR (Net Assimilation Rate) and environmental stressors. This research has provided a comprehensive overview of the complex mechanisms that regulate crop development's vegetative and reproductive phases(Pankaj et al., 2012b; Kumar et al., 2018; Kumar et al., 2018; Kumar et al., 2018; Kumar et al., 2018; Kumar and Dwivedi 2011a; Pandey et al., 2018; Kumar and Dwivedi 2018; Krishna et al., 2018; Kumar and Dwivedi 2020; Kumar et al., 2019).

Table 4.1.13.1 Effect of sowing dates and agrochemicals treatments on Net Assimilation Rate (mg/cm^2/day) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Net Assimilation Rate-2022			Net Assimilation Rate-2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	3.22	1.09	1.09	3.22	4.09	5.09
S0 -Optimum sowing	5.62	0.63	0.63	5.62	3.63	4.63
SL -Late sowing	4.44	1.84	1.84	4.44	4.84	5.84
(Agrochemicals)						
A0- Control	2.75	1.46	1.38	4.75	4.38	5.38
A1-Sodium nitroprusside (250 µM/L)	2.21	0.91	0.91	4.21	3.91	4.91
A2-Salicylic acid (150mg/L)	2.37	1.46	1.46	4.37	4.46	5.46
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	2.37	1.00	1.00	4.37	4.00	5.00
CV (Sowing)	5.11	6.33	5.11	5.14	6.98	5.44
CV (Sowing date and agrochemical)	5.75	7.58	6.12	5.98	6.21	7.65
CD (Sowing)	0.256	0.300	0.301	0.251	0.302	0.301
CD (Agrochemicals)	0.252	0.314	0.315	0.256	0.312	0.316

Table 4.1.13.2 The interaction effect of sowing dates and agrochemicals treatments on Net Assimilation Rate (mg/cm^2/day) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Net Assimilation Rate-2022			Net Assimilation Rate-2023		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
SEA0	1.09^{g} ±0.10	1.19^{bc}±0.02	1.22^{bc}±0.05	3.09^{g}±0.08	3.52^{bc} ±0.95	5.19^{bc}±0.02
SEA1	0.99^{g}±0.16	1.08^{bcd}±0.04	1.12^{bcd}±0.10	2.99^{g}±0.13	4.08^{bcd}±0.04	5.08^{bcd}±0.04
SEA2	1.24^{fg}±0.07	1.20^{bc}±0.08	1.27^{bc}±0.06	3.24^{fg}±0.06	4.20^{bc}±0.07	5.20^{bc}±0.07
SEA3	1.57^{ef}±0.02	0.89^{cde}±0.07	0.92^{cde}±0.01	3.57^{ef}±0.01	3.89^{cde}±0.06	4.89^{cde}±0.06
S0A0	4.31^{a}±0.41	0.59^{de}±0.02	0.62^{de}±0.07	5.64^{a}±0.92	3.59^{de}±0.02	4.59^{de}±0.02
S0A1	3.60^{b}±0.45	0.51^{e}±0.02	0.61^{e}±0.19	5.60^{b}±0.37	3.51^{e}±0.02	4.51^{e}±0.02
S0A2	3.95^{ab}±0.38	0.86^{cde}±0.04	0.89^{cde}±0.05	5.95^{ab}±0.31	3.86^{cde}±0.03	4.86^{cde}±0.03
S0A3	2.64^{c}±0.11	0.60^{de}±0.05	0.63^{de}±0.11	4.64^{c}±0.09	3.60^{de}±0.04	4.60^{de}±0.04
SLA0	2.86^{c}±0.21	2.37^{a}±0.10	2.71^{a}±0.58	4.19^{c}±1.02	4.71^{a}±0.95	5.37^{a}±1.42
SLA1	2.07^{d}±0.08	1.16^{bc}±0.08	1.23^{bc}±0.05	4.07^{d}±0.06	5.16^{bc}±0.84	5.49^{bc}±0.41
SLA2	1.95^{de}±0.23	2.34^{a}±1.03	2.41^{a}±0.92	4.61^{de}±0.79	5.34^{a}±0.84	6.34^{a}±0.84
SLA3	2.90^{c}±0.18	1.52^{b}±0.17	1.55^{b}±.023	4.90^{c}±0.15	4.52^{b}±0.14	5.52^{b}±0.14
CV	5.75	7.58	6.12	5.98	6.21	7.65
CD	0.454	0.555	0.556	0.451	0.554	0.552

Figure 4.1.13.1a. Effect of sowing dates and agrochemicals treatments on Net Assimilation Rate (mg/cm^2/day) of maize at 30, 60, and 90 DAS during spring season 2022

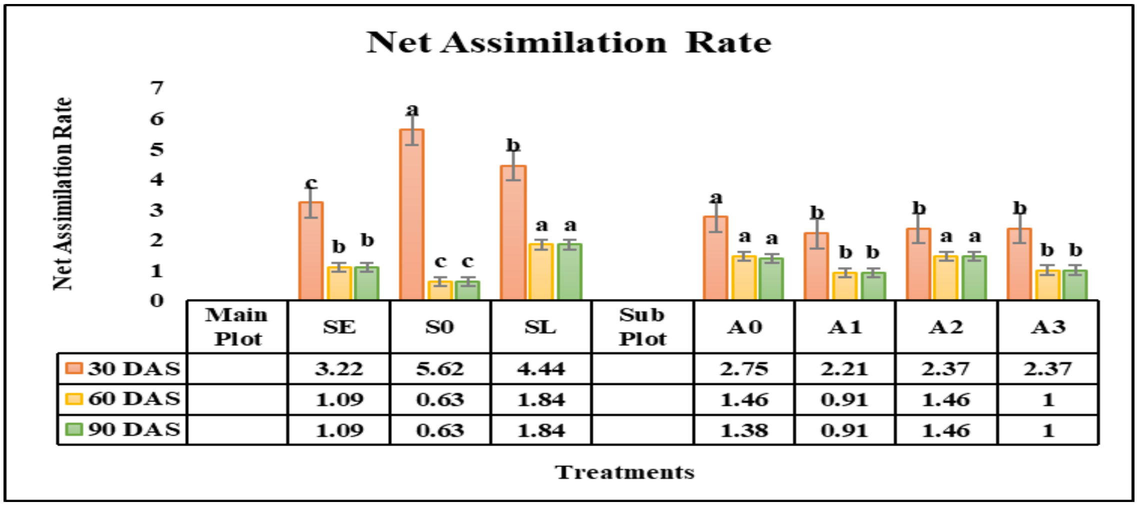
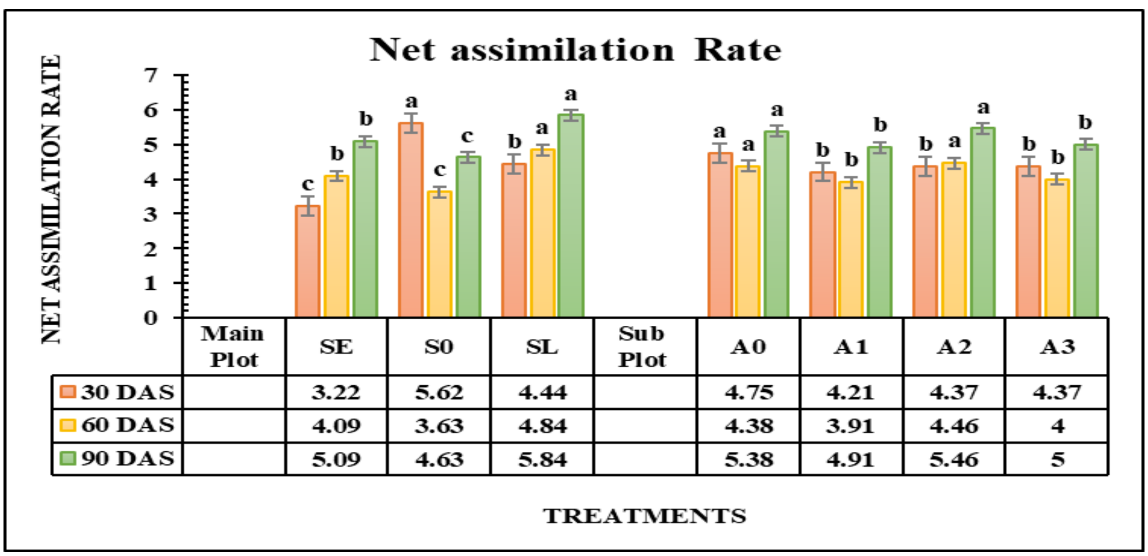


Figure 4.1.13.2b. Effect of sowing dates and agrochemicals treatments on Net Assimilation Rate (mg/cm^2/day) of maize at 30, 60, and 90 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.1.14 Dry Matter Accumulation (%): The impact of sowing dates and agrochemicals on the Dry Matter Accumulation (%) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS (Table 4.1.13.1, 4.1.13.2, and Figure 4.1.13.1a,4.1.13.2b). In 2022 and 2023, there was a significant difference in the percentage of Dry Matter Accumulation (%) sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates, and case of agrochemicals, it was calculated by comparing all the standard with control. Thus, the percentage pattern in the Dry Matter Accumulation (%) was observed at 30, 60, and 90 DAS. It was recorded that early sowing (SE) increased the percentage by 1.30%, and late sowing decreased the percentage by 0.09% compared to the optimum sowing (S0) at 30 DAS. At 60 DAS, the percentage increased by 25.41% in early sowing (SE) and decreased in case of late sowing (SL) by 4.82% as compared to optimum sowing (S0). In the case of 90 DAS, we had the highest percentage of late sowing, i.e. 15.32%, followed by early sowing (SE), i.e. 10.33%, compared to optimum sowing. It was found that in applied agrochemicals, the application of salicylic acids (A2) showed better results by increasing the percentage by 4.99%, 10.14%, and 1.34% at 30, 60, and 90 DAS, respectively, compared to control (A0). In 2023, it was recorded that early sowing increased the percentage by 1.30% compared to optimum sowing at 30 DAS. At 60 DAS, the early sowing increased the rate by 25.33%, and late sowing decreased the percentage by 4.81% compared to optimum sowing (S0). At 90 DAS, the late sowing (SL) showed the highest rate, i.e. 15.45% and early sowing (SE), i.e. 10.08%, respectively, compared to optimum sowing. Among applied agrochemicals, the application of salicylic acid shows a better result by increasing the 0ercentage by 3.04%, 11.21, and 1.13% at 30, 60, and 90 DAS, respectively, compared to control (A0). At 60, DAS A1 showed the better result, with the highest percentage, i.e. 10.02%, followed by A3, i.e. 2,30%, respectively, compared to control (A0). Similar trends were observed at 90 DAS in that the application of sodium nitroprusside increased the percentage by 6.84%, followed by the combined application of sodium nitroprusside and salicylic acid (A3) compared to control (A0). Within the complex realm of crop physiology, the phenomenon known as Dry Matter Accumulation (DMA) assumes a pivotal role in evaluating a plant's reaction to various environmental stressors. This study investigates the intricate dynamics of DMA (Days to Maturity Analysis) in crops exposed to untimely sowing, either occurring too early or too late, compared to the recommended planting schedule. Gaining a comprehensive comprehension of the scientific complexities associated with DMA is imperative to elucidate the intricate dynamics between environmental factors, the timing of germination, and the subsequent growth and reproductive processes of plants. When seeds are planted before reaching their optimal maturity, the resulting seedlings are exposed to various environmental stressors that substantially affect their DNA methylation activity. Late spring frosts present a significant risk, which has the potential to impede the process of optimal dry matter synthesis. From a scientific perspective, it has been observed that being exposed to cold temperatures can have a disruptive effect on crucial physiological processes(Kumar et al., 2021; Kumar and Mistri 2020; Singh and Kumar 2022; Das et al., 2022; Upadhyay et al., 2023; Islam et al., 2023). This includes the metabolic pathways associated with DMA, which affects the overall amount and effectiveness of dry matter accumulation. The repercussions of cold stress are evident in the diminished and irregular DNA methylation patterns observed in crops sown early, affecting their overall biomass and subsequent growth. On the other hand, sowing crops later than usual introduces specific environmental stress factors that impact the development of dry matter accumulation (DMA). The condensed duration of the growing season imposes substantial demands on plants to accelerate their vegetative and reproductive growth. From a scientific standpoint, the shortened time frame may lead to compromised developmental and morphological adjustments (DMA) as plants expedite their growth stages to allocate resources towards reproductive activities. The ability of crops to efficiently utilize their root system for nutrient uptake is hindered by tangible limitations imposed by temporal constraints. The scientific complexities of this process highlight the need for a careful equilibrium to attain an optimal DMA amidst diverse environmental pressures linked to departure from suggested sowing schedules. Determining the appropriate timing for sowing has emerged as a crucial aspect in the scientific examination of DMA, as it allows for the establishment of ideal conditions for the growth and development of crops (Paul et al., 2005; Islam et al., 2023; Siddique et al., 2018; Kumar & Pathak 2018). The temporal occurrence coincides with advantageous ecological circumstances, encompassing factors such as temperature, soil moisture, and daylight duration, all collectively contributing to the effective synthesis of dry matter. From a scientific perspective, this synchronisation facilitates the timely activation of genetic and hormonal processes, resulting in the attainment of uniform and optimal DNA. The suggested timing establishes the foundation for attaining optimal dry matter accumulation, a critical factor in determining the crop's biomass and overall yield capacity. To address the adverse effects of environmental stress on DNA, a scholarly approach investigates the influence of growth regulators. Salicylic acid, renowned for its role in plant defence mechanisms, can be strategically utilized to regulate dry matter accumulation in unfavourable environmental conditions. From a scientific perspective, the activation of stress response genes by salicylic acid has been found to improve a plant's capacity to endure environmental challenges, which could potentially contribute to a more consistent and optimal DNA methylation pattern. This strategic approach is especially pertinent for crops that are sown early, as it provides a scientific method to enhance the resilience of plants against the potential adverse impacts of late frosts on the synthesis of dry matter. In addition, using sodium nitroprusside as a nitric oxide donor offers a scientific intervention for optimising DMA. When sodium nitroprusside is used carefully and deliberately, it impacts important physiological processes, including cell division and elongation, which are essential for the accumulation of dry matter. From a scientific perspective, this application plays a role in developing an ideal DMA (Daylight Management Approach), which is especially advantageous for crops that are sown late and need to enhance their vegetative and reproductive growth despite having a limited growing season. The intricate utilisation of these growth regulators demonstrates their capacity to regulate the physiological reactions of crops when confronted with environmental stressors that arise from deviations in recommended sowing timing. The scientific investigation of environmental stress on DNA in crops reveals a holistic comprehension of the complex dynamics between timing, growth conditions, and vegetative and reproductive development processes. Crops are sown early to face the obstacle of late frosts, which hinder their ability to achieve optimal dry matter accumulation(Sharma et al., 2023; Wu and Li 2022; Mohan et al., 2023; Yadav et al., 2023; Campos et al., 2023). On the other hand, crops that are sown late face the challenge of a shortened growing season, which affects their ability to synthesise dry matter. Determining the appropriate timing for sowing, based on scientific principles, is crucial in creating the most favourable conditions for attaining an optimal desired outcome, known as the ideal DMA. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents tactical interventions for augmenting the resilience of crops, impacting DNA methylation activity and modulating the crop's overall biomass and yield capacity. The ongoing scientific exploration in various fields has contributed to a deeper understanding of the relationship between DNA methylation (DMA) and environmental stressors. This research has provided a comprehensive overview of the complex mechanisms regulating crop growth's vegetative and reproductive phases

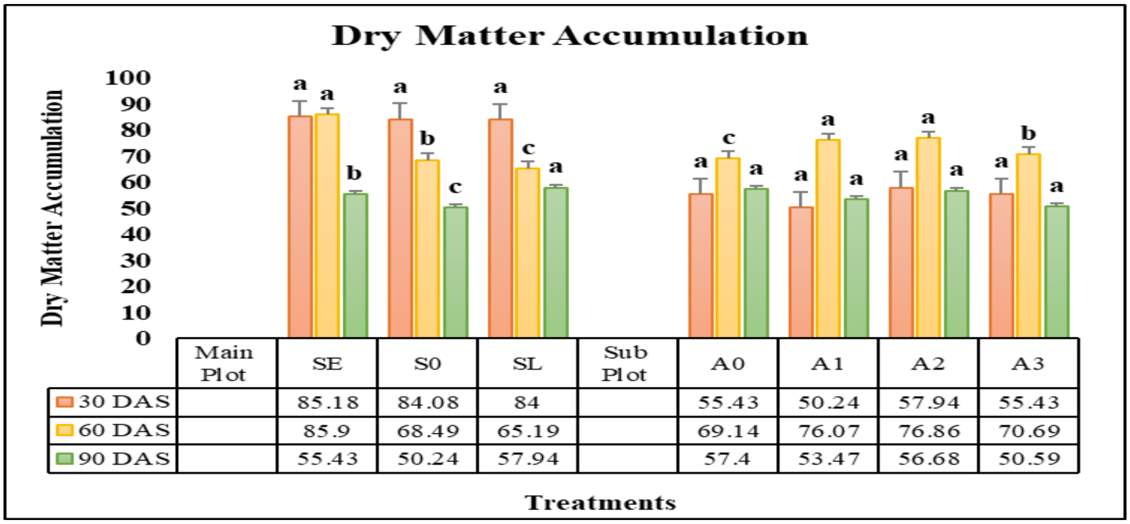
Table 4.1.14.1 Effect of treatments on dry matter accumulation (%) at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Dry Matter Accumulation-2022			Dry Matter Accumulation 2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	85.18	85.90	55.43	85.29	85.84	55.33
S0 -Optimum sowing	84.08	68.49	50.24	84.19	68.49	50.26
SL -Late sowing	84.00	65.19	57.94	84.11	65.19	58.02
(Agrochemicals)						
A0- Control	86.47	69.14	57.40	86.58	69.11	57.40
A1-Sodium nitroprusside (250 µM/L)	82.90	76.07	53.47	83.10	76.04	53.47
A2-Salicylic acid (150mg/L)	83.83	76.86	56.68	83.94	76.86	56.69
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	84.49	70.69	50.59	84.60	70.70	50.59
CV (Sowing)	3.99	2.11	35.66	3.98	2.16	36.04
CV (Sowing date and agrochemical)	5.38	1.11	17.32	5.38	1.10	17.34
CD (Sowing)	3.18	1.74	22.04	3.81	1.79	22.29
CD (Agrochemicals)	4.50	0.80	9.35	4.51	0.79	9.36

Table 4.1.14.2 The interaction effect of sowing dates and agrochemicals treatments on dry matter accumulation (%) at 30, 60, and 90 DAS during spring season 2022 and 2023

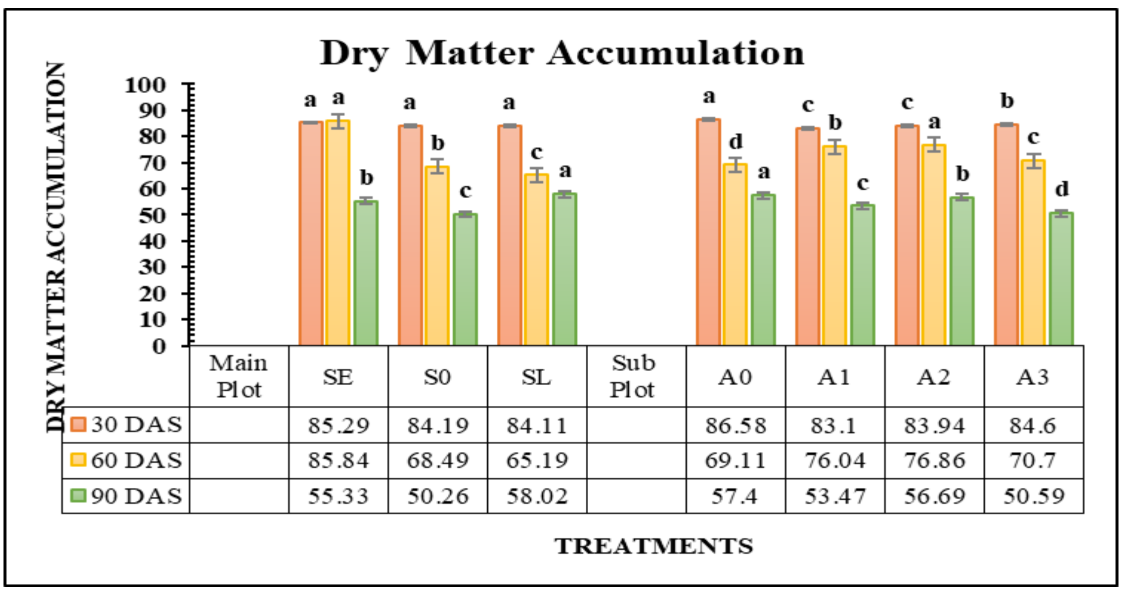
Treatments	Dry Matter Accumulation-2022			Dry Matter Accumulation-2023		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
SEA0	86.6^{a}±4.96	82.2^{a}±4.23	53.1^{f}±1.59	82.67^{a}±4.37	77.43^{a}±10.38	53.17^{f}±1.70
SEA1	86.5^{ab}±1.49	86.6^{ab}±0.52	51.8^{ef}±1.81	86.56^{ab}±1.49	86.54^{ab}±0.35	51.64^{ef}±1.54
SEA2	90.6b±6.46	85.4^{bc}±0.13	64.3^{bc}±1.42	84.08^{b}±1.45	85.39^{bc}±0.08	64.11^{bc}±1.45
SEA3	83.8^{ab}±2.25	84.0^{c}±0.17	52.6^{e}±1.41	83.88^{ab}±2.25	84.04^{c}±0.12	52.43^{e}±1.26
S0A0	84.5ab±4.74	57.1^{i}±1.27	57.3^{d}±6.56	84.64^{ab}±4.74	57.14^{i}±1.46	67.13^{ab}±1.07
S0A1	80.5b±7.04	75.5^{d}±1.72	58.0^{d}±0.65	80.56^{b}±7.04	75.49^{d}±1.88	58.06^{d}±0.70
S0A2	86.7^{ab}±8.56	76.4^{d}±1.27	37.5^{g}±1.15	86.86^{ab}±8.56	76.42^{d}±1.45	37.59±0.97
S0A3	84.6^{ab}±3.48	64.9^{fg}±1.39	38.2^{g}±3.18	84.72^{ab}±3.48	64.93^{fg}±1.59	38.27±3.49
SLA0	82.7^{ab}±2.23	62.8^{h}±1.11	48.5±5.83	78.45^{ab}±7.64	62.77^{h}±1.15	58.57^{d}±7.01
SLA1	81.8^{b}±2.97	66.1^{f}±1.511	70.00^{a}±2.25	81.91^{b}±2.97	66.09^{f}±1.67	65.75^{b}±8.97
SLA2	84.1^{ab}±0.72	68.8^{e}±1.23	68.3^{b}±9.95	84.23^{ab}±0.72	68.80^{e}±1.41	68.37^{a}±10.25
SLA3	85.1^{ab}±4.86	63.1^{gh}±1.61	61.0^{c}±2.04	85.21^{ab}±4.86	63.13^{gh}±1.71	61.08^{c}±1.96
CV	5.38	1.11	17.32	5.38	1.10	17.34
CD	7.70	2.10	25.90	7.70	2.13	26.12

Figure 4.1.14.1a. Effect of sowing dates and agrochemicals on dry matter accumulation (%) at 30, 60, and 90 DAS during spring season 2022



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		85.18	84.08	84		55.43	50.24	57.94	55.43
60 DAS		85.9	68.49	65.19		69.14	76.07	76.86	70.69
90 DAS		55.43	50.24	57.94		57.4	53.47	56.68	50.59

Figure 4.1.14.2b. Effect of sowing dates and agrochemicals on dry matter accumulation (%) at 30, 60, and 90 DAS during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		85.29	84.19	84.11		86.58	83.1	83.94	84.6
60 DAS		85.84	68.49	65.19		69.11	76.04	76.86	70.7
90 DAS		55.33	50.26	58.02		57.4	53.47	56.69	50.59

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2 Biochemical Parameters from maize leaves at 30, 60 and 90 DAS

4.2.1 Chlorophyll Index: The impact of sowing dates and agrochemicals on the Chlorophyll Index was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS shown in (Table 4.2.1.1 4.2.1.2 and Figure 4.2.1.1a, 4.2.1.2b). In 2022 and 2023, there was a significant difference in the percentage of Chlorophyll Index sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals it was calculated by comparing all the mean with control. Thus, the percentage pattern in the Chlorophyll Index was observed at 30, 60, and 90 DAS. In 2022, it was recorded that in the case of early sowing (SE), the percentage decreased by 4.04%, and in late sowing (SL), the percentage increased by 4.75% as compared to the optimum sowing (S0) at 30 DAS. At 60 DAS, the same trends were followed in which early sowing (SE) decreased the percentage by 4.04% and late sowing (SL) increased the percentage by 1.82% as compared to optimum sowing (S0). In case of 90 DAS the early sowing (SE) decreased the percentage by 4.23% and late sowing (SL) decreased by 0.23%, respectively, as compared to the optimum sowing (A0). Among applied agrochemicals, the application of salicylic acid (A2) showed an increase of 11.22%, followed by A3 and A1 by 9.41% and 3.69%, respectively, compared to the control (A0) at 30 DAS. At 60 DAS, the same trends were followed. A2 had the highest percentage, i.e. 8.16, followed by A3 and A1, i.e. 3.60% and 2.34%, respectively, compared to control (A0). At 90 DAS, the highest percentage was found in A2, followed by A1 and A3 by 30.34%, 20.06% and 4.72%, respectively, compared to the control (A0). In 2023, early sowing decreased the percentage by 1.37%, 4.71%, and 4.13% at 30, 60 and 90 DAS, respectively, compared with the optimum sowing (S0). In the case of late sowing (SL) at 30 and 60, the percentage was increased by 4.61% and 1.77%, respectively, but at 90 DAS, it was decreased by 1.19 as compared to the optimum sowing (S0). The applied agrochemicals also showed a better result in that A2 had the highest percentage, i.e. 11.28%, 8.11% and 35.43%, at 30, 60 and 90 DAS, respectively, compared to the control (A0). In the intricate realm of crop physiology, the Chlorophyll Index (CI) is a critical indicator for assessing a plant's response to environmental stressors. This scientific exploration delves into the nuanced dynamics of CI in crops subjected to untimely sowing, either prematurely or belatedly, compared to the recommended planting schedule. Understanding the scientific intricacies of CI is essential for unravelling the complex interplay between environmental conditions, germination timing, and subsequent vegetative and reproductive development. When seeds are planted prematurely, emerging seedlings face an array of environmental stressors that significantly impact CI. Late spring frosts pose a substantial threat, potentially hindering optimal chlorophyll synthesis. Scientifically, exposure to cold temperatures disrupts essential physiological processes, including metabolic pathways involved in chlorophyll production, influencing CI's overall quantity and efficiency. The consequences of this cold stress manifest in reduced and uneven CI in early-sown crops, impacting their overall photosynthetic efficiency and subsequent growth. Conversely, late sowing introduces distinct environmental stressors influencing CI in crops—the compressed growing season pressures plants to expedite vegetative and reproductive development. From a scientific perspective, the abbreviated timeframe may compromise CI as plants hasten through stages to allocate resources toward reproductive activities. Tangible pressure imposed by time constraints compromises crops' capacity to optimize their CI. The scientific intricacies of this process underscore the delicate balance required for achieving an ideal CI in the face of varying environmental stressors associated with deviation from recommended sowing timing. The recommended sowing timing emerges as a critical factor in the scientific investigation of CI, establishing optimal conditions for crop growth and development. The timing aligns with favourable environmental conditions, including temperature, soil moisture, and daylight duration, all contributing to efficient chlorophyll synthesis. Scientifically, this synchronization allows for the timely activation of genetic and hormonal processes, leading to uniform and optimal CI. The recommended timing sets the stage for achieving an ideal chlorophyll index, a vital determinant of the crop's photosynthetic efficiency and yield potential. To mitigate the impact of environmental stress on CI, a scientific approach explores the role of growth regulators. Salicylic acid, known for its involvement in plant defence responses, can be strategically applied to modulate chlorophyll production under adverse conditions. Scientifically, salicylic acid's activation of stress response genes enhances the plant's ability to withstand environmental challenges, potentially promoting a more uniform and optimal CI. This strategic application becomes particularly relevant for early-sown crops, offering a scientific means to fortify plants against the potential detrimental effects of late frosts on chlorophyll synthesis. Moreover, sodium nitroprusside, functioning as a nitric oxide donor, presents a scientific intervention to optimize CI. When applied judiciously, sodium nitroprusside influences crucial physiological processes, such as cell division and elongation, fundamental to chlorophyll production. Scientifically, this application contributes to establishing optimal CI, which is particularly beneficial for late-sown crops striving to expedite vegetative and reproductive growth within the constraints of a shortened growing season. The nuanced use of these growth regulators highlights their potential to modulate the physiological responses of crops facing environmental stressors associated with deviations from recommended sowing timing (Rasmi et al., 2024; Wang et al., 2024; Muhammad et al., 2024; Xu et al., 2024). The scientific exploration of ecological stress on CI in crops unveils a comprehensive understanding of the intricate interplay among timing, growth circumstances, and vegetative and reproductive development. Early-sown crops contend with challenges of late frosts impeding optimal CI, while late-sown counterparts grapple with the stress of a compressed growing season influencing chlorophyll synthesis. The recommended sowing timing, grounded in scientific principles, emerges as a pivotal factor in establishing optimal conditions for achieving an ideal CI. Integrating growth regulators like salicylic acid and sodium nitroprusside into scientific approaches offers strategic interventions to enhance the resilience of crops, influencing CI and shaping overall photosynthetic efficiency and crop yield potential.

Table 4.2.1.1 Effect of treatments on chlorophyll index of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Chlorophyll index-2022			Chlorophyll index-2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	39.59	43.15	47.93	40.79	44.09	49.13
S0 -Optimum sowing	40.16	44.97	50.05	41.36	46.27	51.25
SL -Late sowing	42.07	45.79	49.93	43.27	47.09	50.64
(Agrochemicals)						
A0- Control	38.14	43.06	42.46	39.34	44.36	43.66
A1-Sodium nitroprusside (250 µM/L)	39.55	44.07	50.98	40.75	45.37	52.18
A2-Salicylic acid (150mg/L)	42.58	46.66	57.93	43.78	47.96	59.13
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	42.15	44.74	45.20	43.35	46.04	46.40
CV (Sowing)	1.74	3.70	1.63	1.69	3.59	1.59
CV (Sowing date and agrochemical)	4.10	2.80	2.82	3.98	2.72	2.76
CD (Sowing)	2.44	4.39	7.04	0.79	1.86	0.90
CD (Agrochemicals)	1.39	1.01	1.17	1.64	1.23	1.37

Table 4.2.1.2 The interaction effect of treatments on chlorophyll index of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Chlorophyll index-2022			Chlorophyll index-2023		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
SEA0	35.60^{e}±2.49	38.77^{e}±1.19	40.84^{e}±1.16	36.80^{e}±2.39	40.07^{e}±1.19	42.04^{e}±1.16
SEA1	37.70^{de}±1.78	43.67^{cd}±1.01	51.37^{c}±2.36	38.90^{de}±1.78	44.97^{cd}±1.01	52.57^{c}±2.36
SEA2	42.93^{a}±1.55	46.90^{d}±1.21	58.03^{a}±1.93	44.13^{a}±1.55	48.20^{ab}±1.21	59.23^{a}±1.93
SEA3	42.13^{ab}±2.56	43.27^{d}±1.46	41.51^{e}±2.30	43.33^{ab}±2.56	44.57^{d}±1.46	42.71^{e}±2.30
S0A0	38.23^{cd}±0.96	44.33^{bcd}±2.55	40.48^{e}±1.52	39.43^{cd}±0.96	45.63^{bcd}±2.55	41.68^{e}±1.52
S0A1	39.60^{bcd}±0.89	42.57^{d}±0.96	55.45^{b}±1.53	40.80^{bcd}±0.89	43.87^{d}±0.96	56.65^{b}±1.53
S0A2	41.47^{ab}±1.70	46.03^{abc}±1.37	57.59^{ab}±2.47	42.67^{ab}±1.70	47.33^{abc}±1.37	58.79^{ab}±2.47
S0A3	41.37^{ab}±1.53	46.97^{a}±1.21	46.70^{d}±2.01	42.57^{ab}±1.53	48.27^{a}±1.21	47.90^{d}±2.01
SLA0	40.60^{abc}±0.95	46.10^{abc}±1.25	46.07^{d}±1.32	41.80^{abc}±0.95	47.40^{abc}±1.25	47.27^{d}±1.32
SLA1	41.37^{ab}±1.72	46.00^{abc}±1.25	46.12^{d}±1.88	42.57^{ab}±1.72	47.30^{abc}±1.25	47.32^{d}±1.88
SLA2	43.37^{a}±1.66	47.07^{a}±1.91	58.18^{a}±1.43	44.57^{a}±1.66	48.37^{a}±1.91	59.38^{a}±1.43
SLA3	42.97^{a}±1.29	44.00^{cd}±2.19	47.39^{d}±2.38	44.17^{a}±1.29	45.30^{cd}±2.19	48.59^{d}±2.38
CV	4.10	2.80	2.82	3.98	2.72	2.76
CD	3.33	4.69	7.29	2.59	2.60	2.24

Figure 4.2.1.1a. Effect of sowing dates and agrochemicals treatments on chlorophyll index of maize at 30, 60, and 90 DAS during spring season 2022

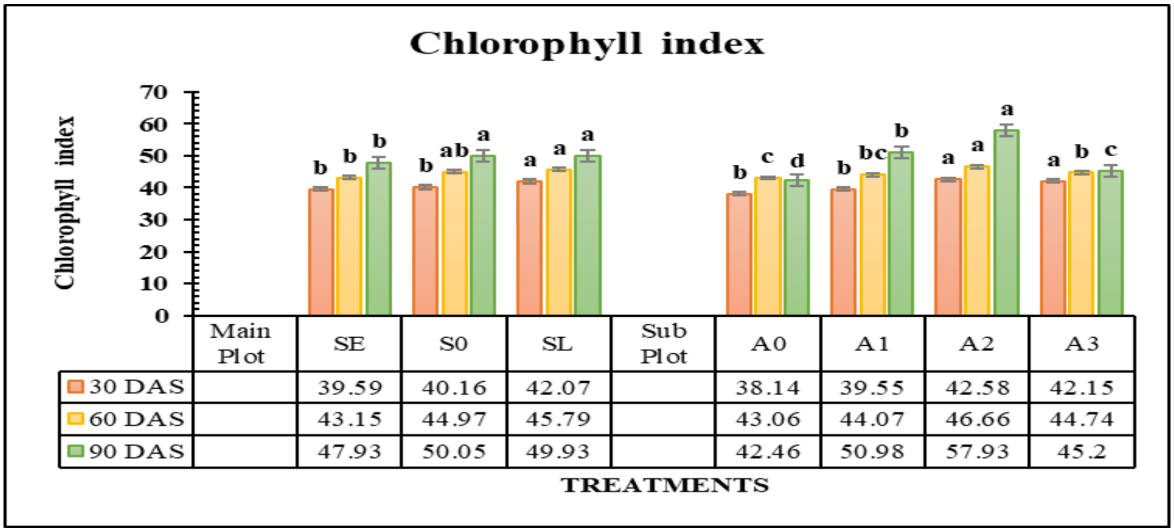
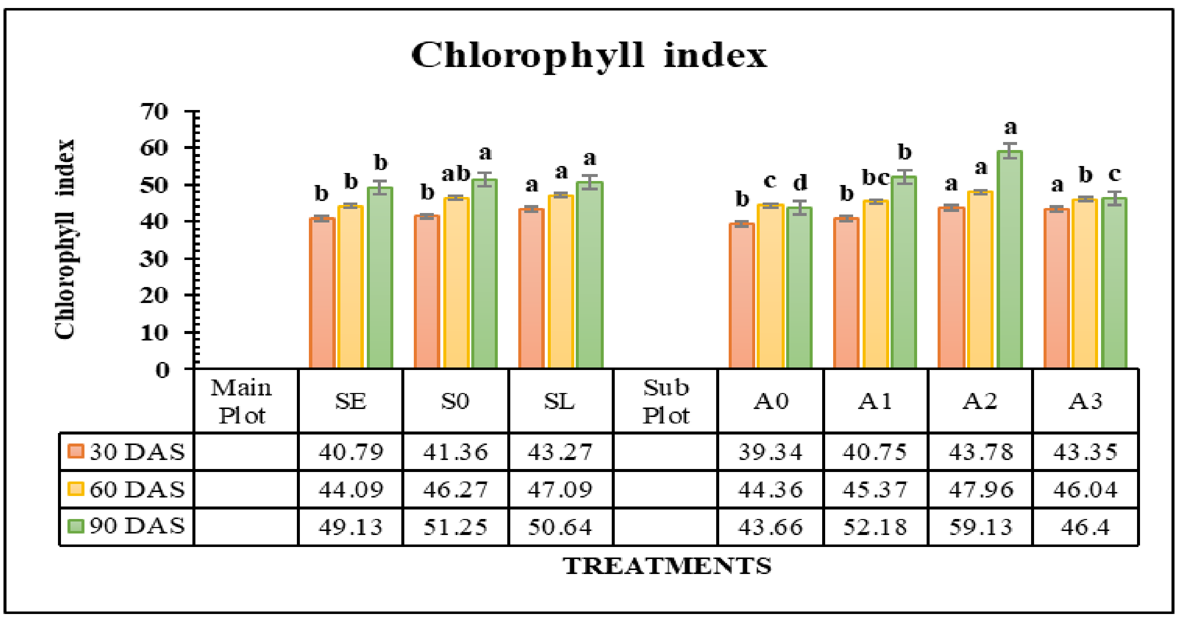


Figure 4.2.1.2b. Effect of sowing dates and agrochemicals treatments on chlorophyll index of maize at 30, 60, and 90 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.2 Chlorophyll a (mg/g Fresh Weight): The effect of different sowing dates and agrochemicals on Chlorophyll a (mg /g Fresh Weight) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was recorded at 30, 60, and 90 DAS shown in (Table 4.2.2.1 4.2.2.2 and Figure 4.2.2.1a, 4.2.2.2b). In 2022 and 2023, there was a significant difference in the percentage of Chlorophyll a (mg /g Fresh Weight) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals; it was estimated by comparing all the mean with control. Thus, the percentage pattern in the Chlorophyll a (mg /g Fresh Weight) was observed at 30, 60, and 90 DAS. In 2022, it was recorded that in late sowing (SL), there was less decreased in percentage by 15.92%, followed by early sowing (SE) by 61.64% as compared to the optimum sowing (S0) at 30 DAS. But at 60 DAS in early sowing, there was less decrease in percentage by 42.99% followed by late sowing (SL) by 59.59% compared to the optimum sowing. In the case of 90 DAS, the late sowing decreased the percentage by 9.25%, and early sowing decreased by 11.13% compared to the optimum sowing. Among the applied agrochemicals, the application of salicylic acid showed a better result by increasing the percentage by 37.41%, 19.84% and 19.80% at different days intervals i.e. 30, 60 and 90 DAS, respectively, compared to the control (A0). The application of sodium nitroprusside also showed a better result by increasing the percentage by 22.09%, 22.88% and 9.79% at 30, 60 and 90 DAS, respectively, compared to the combined application of agrochemicals (A3). In the year 2023, in the case of late sowing, there was less in percentage by 16.76% and 9.60% at 30 and 90 DAS, respectively, as compared to the optimum sowing (A0). In early sowing, their id decreased by 64.876%, 44.29% and 11.50% at 30, 60 and 90 DAS when it was compared to the optimum sowing (A0). The application of agrochemicals also showed better results by increasing the percentage in A2 by 49.47%, 25.64% and 22.765 at 30, 60 and 90 DAS compared to the control (A0). The application of sodium nitroprusside also showed a better result by increasing the percentage by 23.98%, 24.13% and 10.24% at 30, 60 and 90 DAS, respectively, compared to the combined application of agrochemicals (A3). Within the complex realm of crop physiology, Chlorophyll emerges as a pivotal biomolecule, assuming a central function in photosynthesis. Compared to the prescribed planting timetable, this study investigates the intricate mechanisms of Chlorophyll in crops exposed to untimely sowing, either in advance or delayed. Comprehending the scientific complexities associated with Chlorophyll is imperative to elucidate the intricate dynamics between environmental factors, timing of germination, and subsequent growth and reproductive processes in plants. When seeds are planted before the optimal time, the resulting seedlings are exposed to various environmental stressors that significantly affect the amount of Chlorophyll present. Late spring frosts present a considerable risk, potentially impeding the process of optimal chlorophyll synthesis. From a scientific perspective, it has been observed that being exposed to cold temperatures can have a disruptive effect on crucial physiological processes. This includes the metabolic pathways responsible for chlorophyll production, which can impact the quantity and efficiency of Chlorophyll a. The effects of cold stress are observed through a decrease in Chlorophyll levels in early-sown crops, reducing their overall photosynthetic efficiency and subsequent growth. On the other hand, delayed sowing of crops introduces specific environmental stress factors that affect the levels of Chlorophyll a. The condensed duration of the growing season exerts substantial stress on plants, necessitating an acceleration of both vegetative and reproductive growth. From a scientific standpoint, the shortened time frame may reduce Chlorophyll content as plants expedite their growth stages to allocate resources towards reproductive processes. The ability of crops to maximize their Chlorophyll tangible time limitations hinder production (Ashraf and Sonmez 2018; Zangani et al., 2023; Nephali et al., 2020; Singh et al., 2018; Mahdieh et al., 2022; Yasir et al., 2021; Prakash et al., 2021; Naseem et al., 2020; Ghazi 2017; Yadav et al., 2018; Fahad and Bano 2012; Manzoor et al., 2015). The scientific complexities of this process highlight the importance of maintaining a precise equilibrium to attain an optimal Chlorophyll concentration amidst the diverse environmental pressures resulting from deviations in the suggested timing for planting. The timing of sowing is considered a crucial element in the scientific study of Chlorophyll a, as it determines the ideal conditions for the growth and development of crops. The synchronization corresponds to advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which contribute to the practical synthesis of chlorophyll. From a scientific standpoint, this synchronization facilitates the timely activation of genetic and hormonal processes, ultimately resulting in Chlorophyll's uniform and optimal production. The suggested timing establishes the foundation for attaining an optimal chlorophyll index, a crucial factor in the crop's photosynthetic efficiency and overall yield capacity. To alleviate the effects of environmental stress on Chlorophyll, a scientific investigation is undertaken to examine the involvement of growth regulators. Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate chlorophyll synthesis during unfavourable circumstances. From a scientific perspective, salicylic acid's activation of stress response genes has been found to improve a plant's capacity to endure environmental challenges. This process could enhance the uniformity and optimize the content of Chlorophyll a. This strategic approach is especially pertinent for crops that are planted early, as it provides a scientific method to enhance the resilience of plants against the potential adverse impacts of late frosts on the process of chlorophyll synthesis. In addition, the utilization of sodium nitroprusside as a nitric oxide donor offers a scientific intervention for the optimization of Chlorophyll a. When sodium nitroprusside is used carefully and deliberately, it can impact vital physiological processes, including cell division and elongation, which are essential for the production of chlorophyll. From a scientific perspective, this application plays a role in determining the ideal level of Chlorophyll a, which is particularly advantageous for crops that are planted late and need to promote both vegetative and reproductive growth within a limited growing season. The intricate utilization of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronted with environmental stressors linked to deviations from the recommended sowing schedule. Crops are sown early and face the obstacle of late frosts, which hinder the attainment of optimal Chlorophyll levels. On the other hand, crops that are planted late encounter the stress of a shortened growing season, which affects the process of chlorophyll synthesis. Determining the appropriate timing for sowing, based on scientific principles, is crucial in creating favourable conditions for attaining an optimal level of Chlorophyll content. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies provides strategic interventions for improving the resilience of crops. These interventions can impact Chlorophyll levels, influencing the crop's photosynthetic efficiency and yield potential (Najafi et al., 2018; Ishfaq Ahmad et al., 2020; Warsame et al., 2023; Hatfield and Prueger 2015).

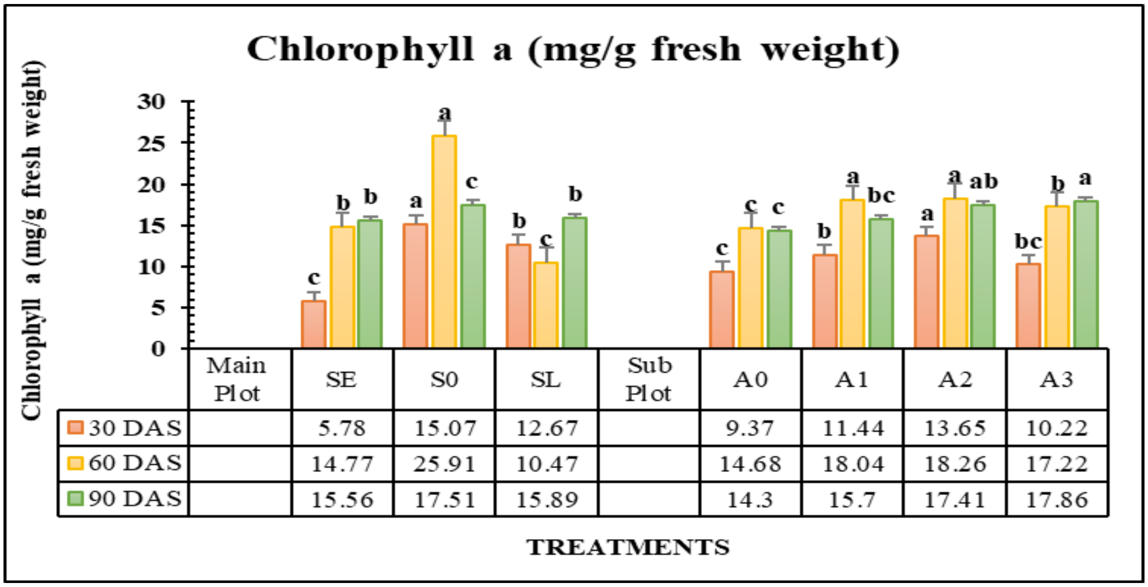
Table 4.2.2.1 Effect of treatments on chlorophyll a (mg /g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Chlorophyll a -2022			Chlorophyll a -2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	5.78	14.77	15.56	5.03	14.01	14.92
S0 -Optimum sowing	15.07	25.91	17.51	14.32	25.15	16.86
SL -Late sowing	12.67	10.47	15.89	11.92	9.71	15.24
(Agrochemicals)						
A0- Control	9.37	14.68	14.30	8.63	13.92	13.66
A1-Sodium nitroprusside (250 µM/L)	11.44	18.04	15.70	10.70	17.28	15.06
A2-Salicylic acid (150mg/L)	13.65	18.26	17.41	12.90	17.49	16.77
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	10.22	17.22	17.86	9.48	16.46	17.22
CV (Sowing)	4.82	1.76	3.35	5.24	1.84	3.49
CV (Sowing date and agrochemical)	11.42	2.17	11.94	12.24	2.27	12.43
CD (Sowing)	0.61	0.33	0.61	0.62	0.34	0.63
CD (Agrochemicals)	1.26	0.36	1.92	1.25	0.35	1.93

Table 4.2.2.2 Interaction effect of treatments on chlorophyll a (mg /g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

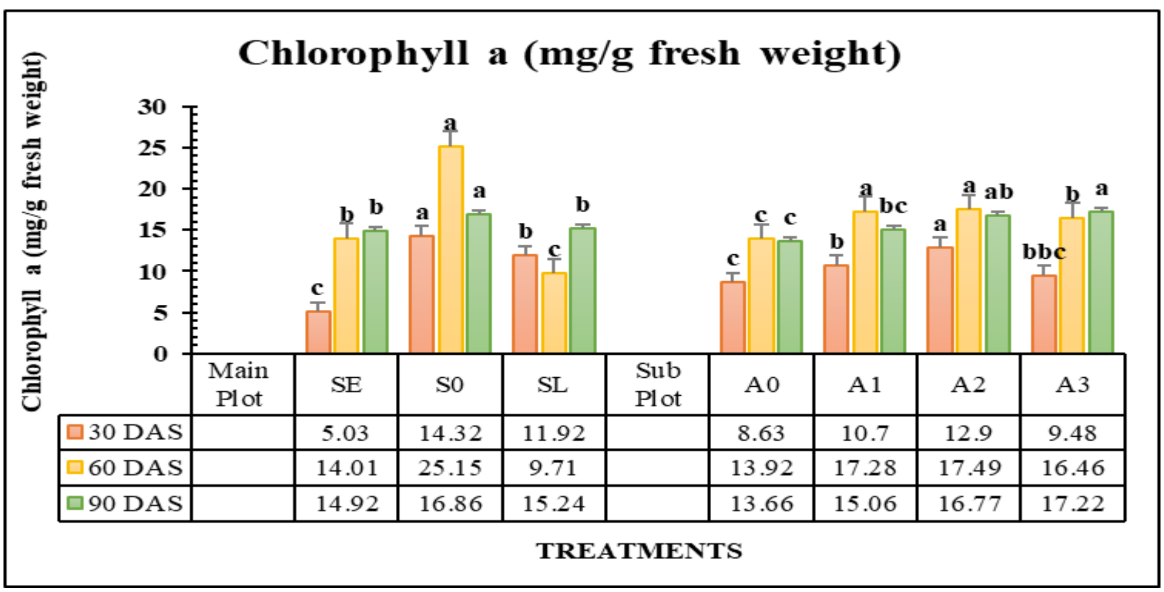
Treatments	Chlorophyll a-2022			Chlorophyll a-2023		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
SEA0	3.87^{e}±0.33	13.43^{f}±0.06	14.44^{cd}±1.22	3.13^{e}±0.33	12.67^{f}±0.06	13.80^{cd}±1.22
SEA1	5.24^{e}±1.45	16.06^{d}±0.51	16.69^{bc}±3.92	4.50^{e}±1.45	15.29^{d}±0.51	16.05^{bc}±3.92
SEA2	8.27^{d}±1.56	14.91^{e}±0.68	16.58^{bcd}±1.02	7.52^{d}±1.56	14.15^{e}±0.68	15.94^{bcd}±1.02
SEA3	5.75^{e}±0.70	14.71^{e}±0.05	14.56^{cd}±4.10	5.00^{e}±0.70	13.95^{e}±0.05	13.91^{cd}±4.10
S0A0	15.44^{b}±0.36	23.57^{c}±0.20	13.70^{d}±0.77	14.70^{b}±0.71	22.81^{c}±0.20	13.06^{d}±0.77
S0A1	15.67^{b}±0.63	27.92^{b}±0.14	14.91^{cd}±0.33	14.93^{b}±0.36	27.15^{b}±0.14	14.26^{cd}±0.33
S0A2	18.99^{a}±0.57	28.61^{a}±0.51	18.47^{b}±0.13	18.25^{a}±0.63	27.85^{a}±0.51	17.83^{b}±0.13
S0A3	10.17^{d}±0.24	23.55^{c}±0.15	22.96^{a}±0.18	9.43^{d}±0.57	22.79^{c}±0.15	22.32^{a}±0.18
SLA0	8.81^{d}±0.13	7.06^{i}±0.14	14.78^{cd}±0.11	8.07^{d}±0.24	6.30^{i}±0.14	14.14^{cd}±0.11
SLA1	13.43^{c}±1.87	10.16^{h}±0.17	15.51^{cd}±0.39	12.68^{c}±0.13	9.40^{h}±0.17	14.87^{cd}±0.39
SLA2	13.69^{bc}±2.34	11.27^{g}±0.14	17.20^{bc}±0.12	12.95^{bc}±1.87	10.50^{g}±0.14	16.55^{bc}±0.12
SLA3	14.76^{bc}±1.21	13.41^{f}±0.73	16.07^{bcd}±0.13	14.02^{bc}±2.34	12.65^{f}±0.73	15.43^{bcd}±0.13
CV	11.42	2.17	11.94	12.24	2.27	12.43
CD	1.98	0.64	2.95	1.98	0.65	2.96

Figure 4.2.2.1a. Effect of sowing dates and agrochemicals treatments on chlorophyll a (mg /g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		5.78	15.07	12.67		9.37	11.44	13.65	10.22
60 DAS		14.77	25.91	10.47		14.68	18.04	18.26	17.22
90 DAS		15.56	17.51	15.89		14.3	15.7	17.41	17.86

Figure 4.2.2.2b. Effect of sowing dates and agrochemicals treatments on chlorophyll a (mg /g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		5.03	14.32	11.92		8.63	10.7	12.9	9.48
60 DAS		14.01	25.15	9.71		13.92	17.28	17.49	16.46
90 DAS		14.92	16.86	15.24		13.66	15.06	16.77	17.22

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.3 Chlorophyll b (mg /g Fresh Weight): The effect of different sowing dates and agrochemicals on Chlorophyll b (mg /g Fresh Weight) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was recorded at 30, 60, and 90 DAS shown in (Table 4.2.3.1 4.2.3.2 4.2.3.3 and 4.2.3.4 and Figure 4.2.3.1a, 4.2.3.2b). In 2022 and 2023, there was a significant difference in the percentage of Chlorophyll b (mg /g Fresh Weight) sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals; it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Chlorophyll b (mg /g Fresh Weight) was observed at 30, 60, and 90 DAS. It was recorded that late sowing decreased the percentage by 26.54%, and early sowing (SE) decreased by 43.00%, respectively, compared to the optimum sowing (S0) at 30 DAS. At 60 DAS, the late and early sowing decreased the percentage by 55.61% and 67.59%, respectively, compared to the optimum sowing. In the case of 90 DAS, the early sowing increased the percentage by 10.09%, and the late sowing decreased the rate by 3.88% compared to the optimum sowing (S0). Among applied agrochemicals, the application of salicylic acid (A2) showed a better result by increasing the percentage by 21.37%, 51.74% and 14.65% at 30, 60 and 90 DAS, respectively, compared to control (A0). The application of sodium nitroprusside also increased the percentage by 10.5%, 36.34% and 49.35% at 30, 60 and 90 DAS, respectively, compared to control (A0). In 2023, it was found that early sowing (SE) decreased the percentage by 53.47%, and late sowing (SL) decreased the rate by 33.16%, respectively, at 30 DAS. AT 60 DAS, early sowing (SE) reduced the percentage by 72.64%, and late sowing also decreased the rate by 59.77% compared to the optimum sowing (S0). But at 90 DAS, early sowing (SE) increased the percentage by 11.61%, and late sowing decreased by 4.78%, respectively, compared to the optimum sowing (S0). Among the applied agrochemicals at 30 DAS, the sodium nitroprusside (A1) showed the better result by increasing the percentage by 70.18%, followed by A2 and A3, i.e.69.56% and 57.23 respectively, as compared to the control (A0,). At 60, DAS A2 showed the maximum percentage, i.e., 83.94%, followed by A1 and A3i.e 43.09% and 20%, respectively, compared to the control (A0) and in the case of 90, DAS A1 showed the maximum percentage, i.e., 59.54%, compared to other applied agrochemicals. In the complex field of crop physiology, Chlorophyll b assumes a central position as a vital biomolecule, exerting a fundamental influence on photosynthesis. This study investigates the intricate dynamics of Chlorophyll b in crops exposed to untimely sowing, either before or after the recommended planting schedule. Comprehending the scientific intricacies associated with Chlorophyll b is imperative to decipher the intricate interactions among environmental factors, timing of germination, and subsequent growth and reproductive processes in plants. The premature planting of seeds exposes emerging seedlings to various environmental stressors, substantially affecting chlorophyll b's content. Late spring frosts present a significant risk, which has the potential to impede the process of optimal chlorophyll synthesis. From a scientific perspective, it has been observed that exposure to cold temperatures can have a detrimental effect on crucial physiological processes. This includes disrupting metabolic pathways responsible for chlorophyll production, thereby impacting the quantity and efficiency of Chlorophyll b. The effects of cold stress are evident in early-sown crops through a decrease in chlorophyll B levels, resulting in an uneven distribution. This, in turn, negatively affects the overall efficiency of photosynthesis and subsequent growth of the crops. On the other hand, delayed sowing of crops introduces specific environmental stress factors that impact the levels of Chlorophyll b. The compressed duration of the growing season imposes considerable stress on plants, necessitating an acceleration of both vegetative and reproductive growth. From a scientific standpoint, the shortened time frame could potentially reduce Chlorophyll b content as plants expedite their growth stages to allocate resources towards reproductive activities. Tangible limitations imposed by temporal constraints hinder the ability of crops to maximize their Chlorophyll b content effectively. The scientific complexities of this process highlight the importance of maintaining a precise equilibrium to attain an optimal level of Chlorophyll b despite diverse environmental stressors that arise from deviating from the suggested timing for sowing. The timing of sowing is considered a crucial factor in scientific research on Chlorophyll b, as it determines the most favourable conditions for crop growth and development (Najafi et al., 2018; Ishfaq Ahmad et al., 2020; Warsame et al., 2023; Hatfield and Prueger 2015; Pachauri et al., 2014; Shrestha and Tripathi 2018). The synchronization corresponds to advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which contribute to the practical synthesis of chlorophyll. From a scientific perspective, this synchronization facilitates the timely activation of genetic and hormonal processes, resulting in a consistent and optimal Chlorophyll b content. The suggested timing establishes the foundation for attaining an optimal chlorophyll index, a crucial factor in the crop's photosynthetic efficiency and overall yield potential. To address the effects of environmental stress on Chlorophyll b, a scientific investigation is undertaken to examine the involvement of growth regulators. Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate chlorophyll synthesis during unfavourable circumstances. From a scientific standpoint, salicylic acid's activation of stress response genes has improved a plant's capacity to endure environmental stressors. This may result in a more consistent and ideal Chlorophyll b concentration. This strategic approach is especially pertinent for crops that are planted early, as it provides a scientific method to enhance the resilience of plants against the potential adverse impacts of late frosts on the process of chlorophyll synthesis. In addition, using sodium nitroprusside as a nitric oxide donor offers a scientific intervention to optimize Chlorophyll b. When sodium nitroprusside is applied carefully and deliberately, it influences vital physiological processes, including cell division and elongation, which are fundamental to chlorophyll production. The scientific investigation of the impact of environmental stress on Chlorophyll b in crops provides a thorough comprehension of the complex interaction between timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops that are sown early face the obstacle of late frosts, which hinder the attainment of optimal chlorophyll B levels. On the other hand, crops that are planted late encounter the challenge of a condensed growing season, which affects the process of chlorophyll synthesis. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions for improving the resilience of crops. Investigating Chlorophyll B and its interaction with environmental stressors provides valuable insights into the complex mechanisms regulating crop development's vegetative and reproductive phases (Najafi et al., 2018; Ishfaq et al., 2020; Warsame et al., 2023; Hatfield and Prueger 2015; Pachauri et al., 2014; Shrestha and Tripathi 2018; Alam et al., 2020; Khan and Khan 2013).

Table 4.2.3.1 Effect of treatments on chlorophyll b (mg /g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Chlorophyll b-2022			Chlorophyll b-2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	2.77	3.03	5.67	1.81	2.38	4.90
S0 -Optimum sowing	4.86	9.35	5.15	3.89	8.70	4.39
SL -Late sowing	3.57	4.15	4.95	2.60	3.50	4.18
(Agrochemicals)						
A0- Control	2.55	4.21	4.66	1.59	3.55	3.89
A1-Sodium nitroprusside (250 µM/L)	5.24	5.74	6.96	4.28	5.08	6.21
A2-Salicylic acid (150mg/L)	3.67	7.18	5.68	2.71	6.53	4.92
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	3.46	4.92	3.72	2.50	4.26	2.96
CV (Sowing)	15.26	8.65	11.18	15.67	8.34	11.89
CV (Sowing date and agrochemical)	16.12	8.44	5.83	16.22	8.34	5.89
CD (Sowing)	0.64	0.54	0.66	0.63	0.52	0.65
CD (Agrochemicals)	0.59	0.46	0.30	0.58	0.45	0.32

Table 4.2.3.2 Interaction effect of treatments on chlorophyll b (mg /g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Chlorophyll b-2022			Chlorophyll b-2023		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
SEA0	2.12^{f} ±0.07	2.45^{g}±0.66	4.37^{d}±0.39	1.15^{f}±0.40	1.80^{g}±1.01	3.61^{d}±0.46
SEA1	2.79^{ef}±0.70	3.11^{fg}±0.18	7.09^{b}±0.18	1.82^{ef}±0.78	2.45^{fg}±0.34	6.32^{b}±0.39
SEA2	3.55^{bcde}±1.63	3.57^{ef}±0.10	5.82^{c}±0.22	2.58^{bcde}±1.38	2.92^{ef}±0.13	5.06^{c}±0.11
SEA3	2.65^{ef}±0.13	3.02^{fg}±0.36	5.41^{c}±0.24	1.69^{ef}±0.20	2.36^{fg}±0.21	4.65^{cd}±0.24
S0A0	3.45^{cde}±0.20	7.07^{c}±0.37	5.70^{c}±0.73	2.48^{cde}±0.18	6.41^{c}±0.40	4.94^{cd}±0.88
S0A1	8.34^{a}±0.15	9.55^{b}±0.04	8.51^{a}±0.15	7.38^{a}±0.25	8.89^{b}±0.21	7.75^{a}±0.17
S0A2	4.27^{bcd}±0.42	13.45^{a}±0.32	5.29^{c}±0.18	3.30^{bcd}±0.29	12.79^{a}±0.34	4.52^{cd}±0.37
S0A3	3.38^{cde}±0.35	7.37^{c}±0.31	1.14^{f}±0.22	2.42^{cde}±0.35	6.71^{c}±0.36	0.38^{e}±0.34
SLA0	2.10^{f}±0.24	3.12^{fg}±1.14	3.91^{e}±0.59	1.14^{f}±0.27	2.46^{fg}±1.55	3.15^{d}±0.85
SLA1	4.62^{b}±0.19	4.57^{d}±0.30	5.30^{c}±0.24	3.66^{b}±0.19	3.92^{d}±0.37	4.53^{cd}±0.25
SLA2	3.22^{de}±0.11	4.55^{d}±0.16	5.96^{c}±0.14	2.25^{de}±0.08	3.89^{d}±0.15	5.20^{c}±0.60
SLA3	4.36^{bc}±0.62	4.38^{de}±0.39	4.64^{d}±0.62	3.40^{bc}±0.62	3.73^{de}±0.36	3.87^{d}±0.66
CV	16.12	8.44	5.83	16.22	8.34	5.89
CD	1.09	0.87	0.80	1.10	0.86	0.80

Figure 4.2.3.1a. Effect of sowing dates and agrochemicals treatments on chlorophyll b (mg /g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022

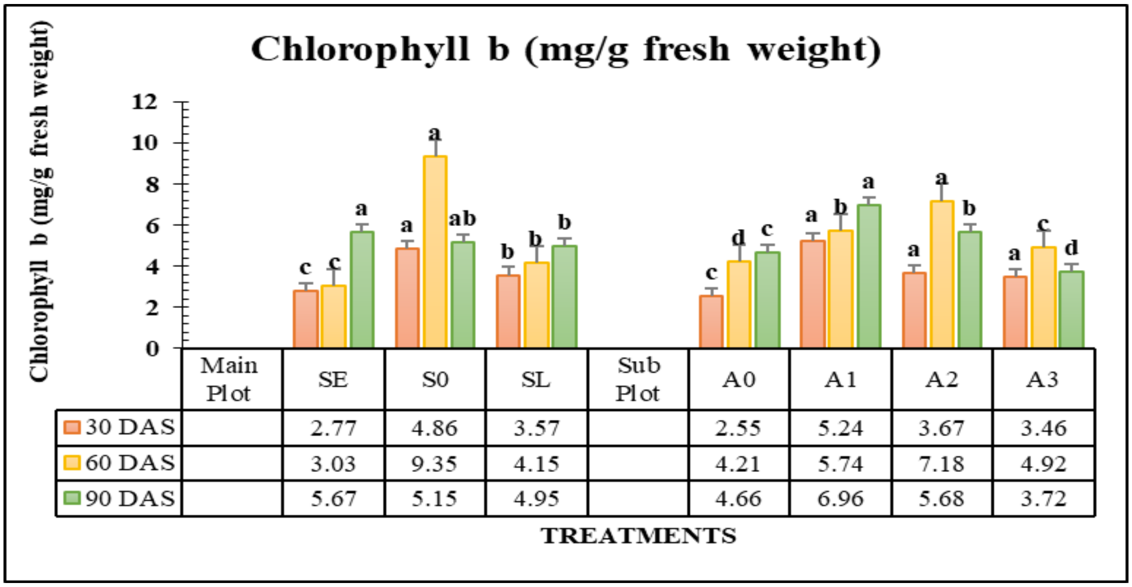
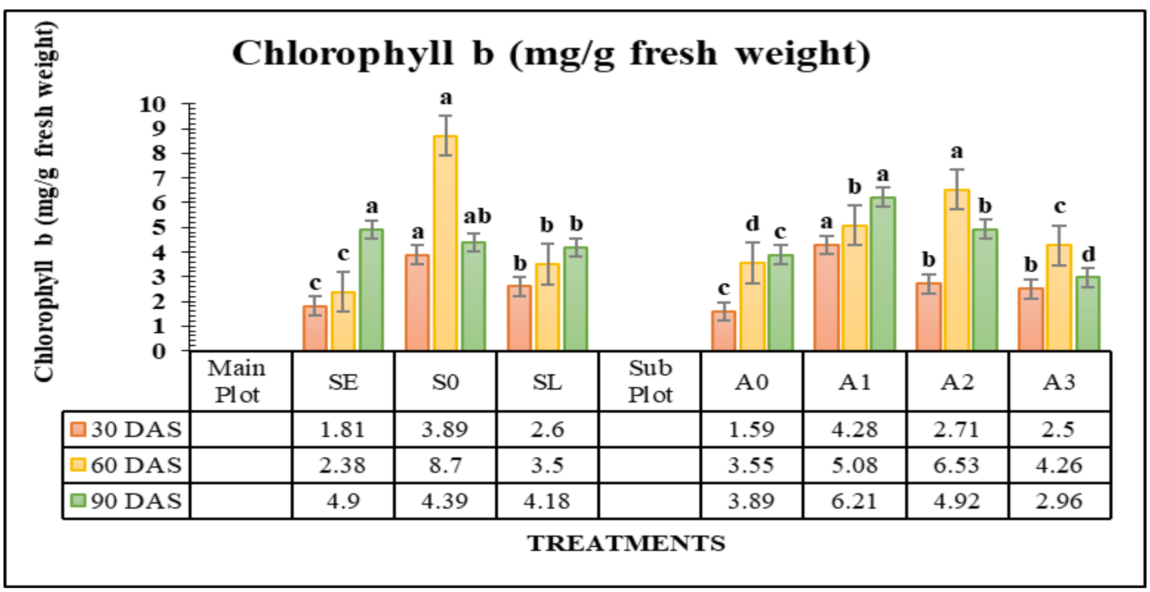


Figure 4.2.3.2b. Effect of sowing dates and agrochemicals treatments on chlorophyll b (mg /g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.4 Ratio of chlorophyll a and b: The impact of sowing dates and agrochemicals on the chlorophyll a and b ratio was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS (Table 4.2.4.1, 4.2.4.2 and Figure 4.2.4.1a, 4.2.4.2b). In 2022 and 2023, there was a significant difference in the percentage of Ratio of chlorophyll a and b sowing dates and agrochemicals. The observed rate was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with the control. Thus, the percentage pattern in the chlorophyll a and b ratio was observed at 30, 60, and 90 DAS. It was recorded that early sowing (SE) decreased the percentage by 24.71%, and late sowing increased the rate by 15.58% compared to the optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing showed a better result by increasing the percentage by 80.86%, and late sowing (SL) decreased the rate by 3.57% compared to the optimum sowing (S0). In the case of 90 DAS, early and late sowing decreased the percentage by 82.17% and 79.05%, respectively, compared with optimum sowing. Among applied agrochemicals, the application of salicylic acid (A2) showed a better result by decreasing the percentage to 5.86, followed by A3 and A1, i.e. 26.66% and 42.35%, respectively, at 30 DAS. At 60 DAS, the combined application A3 showed a better result by decreasing the percentage by 12.85% compared to other agrochemicals, and similarly, at 90 DAS, A3 increased the rate by 56.7% compared to the control (A0). In 2023, the early sowing decreased the percentage by 29.68%, and late sowing (SL) increased the rate by 18.94 compared to the optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing increased the rate by 10.45% and decreased by 4.60% in late sowing compared to optimum sowing. But in the case of 90 DAS, the early and late sowing decreased the percentage by 84.78% and 81.56%, respectively, compared to optimum sowing. Among the applied agrochemicals, the application of salicylic acid (A2) showed a better result by decreasing the percentage by 3.94%, 32.50%, and 7.56% at 30, 60, and 90 DAS, respectively, as compared to the control (A0). In the complex realm of crop physiology, the Chlorophyll a to Chlorophyll b ratio assumes a crucial role as a significant parameter, providing valuable insights into the photosynthetic efficiency of plants. Compared to the recommended planting timeframe, this study investigates the intricate dynamics of the Chlorophyll a/b ratio in crops exposed to untimely sowing, either through premature or delayed planting.

Comprehending this ratio's scientific intricacies is imperative to decipher the intricate interplay among environmental conditions, timing of germination, and subsequent development of vegetation and reproduction. The premature planting of seeds exposes emerging seedlings to various environmental stressors, significantly impacting the Chlorophyll a/b ratio. Late spring frosts present a considerable risk, potentially impeding the process of optimal chlorophyll synthesis. From a scientific perspective, it has been observed that exposure to cold temperatures can interfere with crucial physiological processes. This includes the metabolic pathways responsible for chlorophyll production, affecting the equilibrium between Chlorophyll a and Chlorophyll b. The repercussions of cold stress are evident in early-sown crops through an altered and suboptimal Chlorophyll a/b ratio, adversely affecting their overall photosynthetic efficiency and subsequent growth. On the other hand, sowing crops later than usual introduces specific environmental stress factors that impact the Chlorophyll a/b ratio. The condensed duration of the growing season imposes considerable stress on plants, necessitating an acceleration of both vegetative and reproductive growth. From a scientific standpoint, the shortened time frame could lead to an altered Chlorophyll a/b ratio as plants expedite their growth stages to allocate resources towards reproductive processes. Tangible time limitations hinder the ability of plants to maximize their Chlorophyll a/b ratio(Najafi et al., 2018; Ishfaq et al., 2020; Warsame et al., 2023; Hatfield and Prueger 2015; Pachauri et al., 2014; Shrestha and Tripathi 2018; Kumar and Singh 2019; Vetter et al., 2023; Kumar and Goh 1999; Bolan et al., 2011; Rahman et al., 2022; Ventura et al., 2010; Kutman 2023; Yao et al., 2017; Iqbal et al., 2018). The scientific complexities of this process highlight the need for a careful equilibrium to attain an optimal Chlorophyll a/b ratio amidst diverse environmental stressors linked to deviations from the recommended timing for sowing. The timing of sowing is considered a crucial element in the scientific study of the Chlorophyll a/b ratio, as it determines the ideal conditions for crop growth and development. The synchronization corresponds to advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which contribute to the practical synthesis of chlorophyll. From a scientific perspective, this synchronization facilitates the timely activation of genetic and hormonal processes, resulting in a well-balanced and optimal Chlorophyll a/b ratio. The suggested timing establishes the foundation for attaining an optimal photosynthetic equilibrium, a crucial factor in determining the crop's overall photosynthesis efficiency and yield potential. To address the consequences of environmental stress on the Chlorophyll a/b ratio, a scholarly investigation examines the influence of growth regulators. Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate chlorophyll synthesis during unfavourable circumstances. From a scientific standpoint, salicylic acid's activation of stress response genes has been found to improve a plant's capacity to endure environmental challenges. This process has the potential to facilitate a more balanced Chlorophyll a/b ratio (Alam et al., 2020; Khan and Khan 2013; Dahmardeh 2010; Jin-gui et al., 2023). This strategic approach is especially significant for crops that are sown early, as it provides a scientific method to enhance the resilience of plants against the potential adverse impacts of late frosts on the process of chlorophyll synthesis. Furthermore, using sodium nitroprusside as a nitric oxide donor offers a scientific intervention to optimize the Chlorophyll a to Chlorophyll b ratio. When used carefully and deliberately, sodium nitroprusside impacts vital physiological processes, including cell division and elongation, essential for producing chlorophyll. From a scientific perspective, this application plays a role in determining an ideal Chlorophyll a/b ratio. This is especially advantageous for crops planted late and must enhance their vegetative and reproductive growth despite having a limited growing season. The intricate utilization of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from suggested sowing schedules. The scientific investigation of the impact of environmental stress on the Chlorophyll a/b ratio in crops provides a thorough comprehension of the complex dynamics involving timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops that are sown early face the obstacle of late frosts, which hinder the achievement of an optimal Chlorophyll a/b ratio. On the other hand, crops that are planted late encounter the challenge of a shortened growing season, which affects chlorophyll synthesis. Establishing optimal conditions for achieving an ideal Chlorophyll a/b ratio is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions for improving the resilience of crops. These interventions can impact the

Chlorophyll a/b ratio, influencing the crop's overall photosynthetic efficiency and yield potential. Investigating the Chlorophyll a/b ratio and its relationship with environmental stressors provides valuable insights into the complex mechanisms regulating crop development's vegetative and reproductive phases (Najafi et al., 2018; Ishfaq et al., 2020; Warsame et al., 2023; Hatfield and Prueger 2015; Pachauri et al., 2014; Shrestha and Tripathi 2018; Alam et al., 2020; Yao et al., 2017; Iqbal et al., 2018).

Table 4.2.4.1 Effect of treatments on ratio of chlorophyll a and b of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Ratio of Chlorophyll a and b 2022			Ratio of Chlorophyll a and b 2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	3.96	7.09	3.77	3.08	6.22	3.12
S0 -Optimum sowing	5.26	3.92	21.15	4.38	3.04	20.50
SL -Late sowing	6.08	3.78	4.43	5.21	2.90	3.78
(Agrochemicals)						
A0- Control	6.21	5.68	4.35	5.33	4.80	3.70
A1-Sodium nitroprusside (250 µM/L)	3.58	4.78	3.20	2.70	3.91	2.55
A2-Salicylic acid (150mg/L)	6.00	4.12	4.08	5.12	3.24	3.42
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	4.61	5.15	27.51	3.74	4.27	26.86
CV (Sowing)	19.12	10.34	108.31	23.08	12.57	116.06
CV (Sowing date and agrochemical)	24.10	23.97	110.38	29.09	29.13	118.27
CD (Sowing)	1.10	0.57	12.01	1.11	0.58	10.23
CD (Agrochemicals)	1.21	1.17	10.70	1.23	1.13	11.22

Table 4.2.4.2 The interaction effect of treatments on ratio of chlorophyll a and b of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	**Ratio of Chlorophyll a and b-2022**			**Ratio of Chlorophyll a and b-2023**		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
SEA0	3.88^{de}±0.47	8.64^{a}±2.97	4.49^{b}±0.19	2.73^{de}±0.47	7.77^{a}±2.97	3.83^{b}±0.19
SEA1	3.82^{de}±0.41	7.14^{ab}±0.65	3.19^{b}±0.60	2.62^{de}±0.84	6.27^{ab}±0.65	2.54^{b}±0.60
SEA2	3.95b^{cde}±1.53	5.73^{bc}±0.38	3.80^{b}±0.08	4.04^{bcde}±2.78	4.86^{bc}±0.38	3.15^{b}±0.08
SEA3	3.78^{de}±0.25	6.87^{ab}±0.90	3.62^{b}±0.72	2.96^{de}±0.22	6.00^{ab}±0.90	2.97^{b}±0.72
S0A0	6.35^{ab}±0.38	4.44^{cd}±0.23	3.32^{b}±0.26	5.96^{ab}±0.73	3.57^{cd}±0.23	2.67^{b}±0.26
S0A1	2.92^{e}±0.03	3.93^{cd}±0.01	2.49^{b}±0.07	2.02^{e}±0.03	3.05^{cd}±0.01	1.84^{b}±0.07
S0A2	6.96^{abc}±0.03	3.05^{d}±0.09	4.60^{b}±0.18	5.59^{abc}±0.84	2.18^{d}±0.09	3.95^{b}±0.18
S0A3	5.22^{bcde}±0.19	4.27^{cd}±0.17	5.00^{a}±1.57	3.97^{bcde}±0.76	3.40^{cd}±0.17	6.88^{a}±3.76
SLA0	7.35^{a}±1.63	3.96^{cd}±1.76	5.26^{b}±0.94	7.32^{a}±1.56	3.08^{cd}±1.76	4.60^{b}±0.94
SLA1	4.45^{cde}±0.25	3.29^{d}±0.22	3.94^{b}±0.26	3.48^{cde}±0.22	2.41^{d}±0.22	3.29^{b}±0.26
SLA2	6.82^{ab}±0.59	3.58^{d}±0.08	3.84^{b}±0.10	5.76^{ab}±0.81	2.70^{d}±0.08	3.19^{b}±0.10
SLA3	4.34^{bcd}±0.13	4.31^{cd}±0.58	4.71^{b}±0.71	4.30^{bcd}±1.51	3.43^{cd}±0.58	4.06^{b}±0.71
CV	24.10	23.97	110.38	29.09	29.13	118.27
CD	2.12	1.84	19.89	2.22	1.86	20.52

Figure 4.2.4.1a. Effect of sowing dates and agrochemicals treatments on ratio of chlorophyll a and b of maize at 30, 60, and 90 DAS during spring season 2022

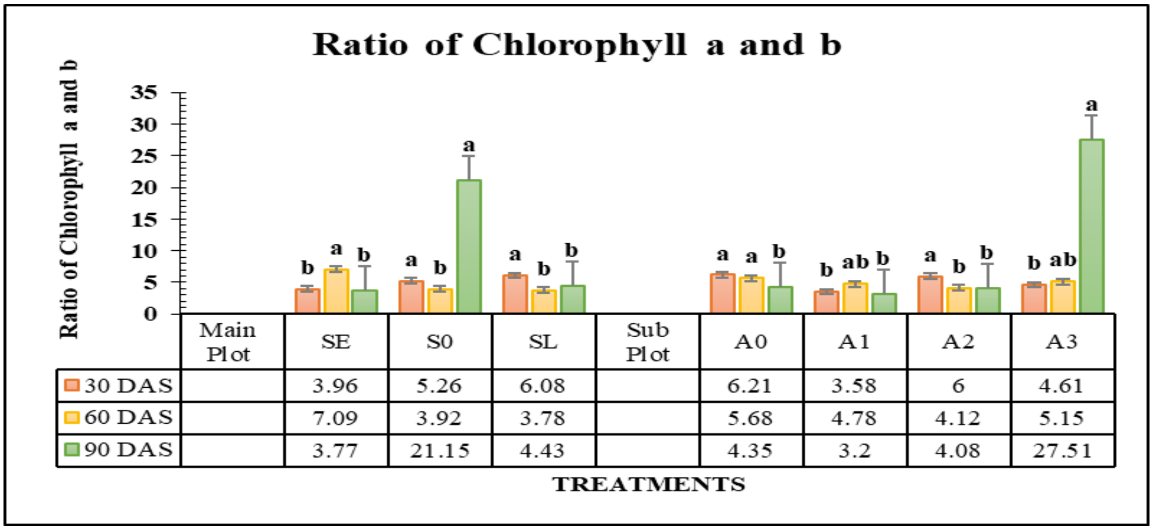
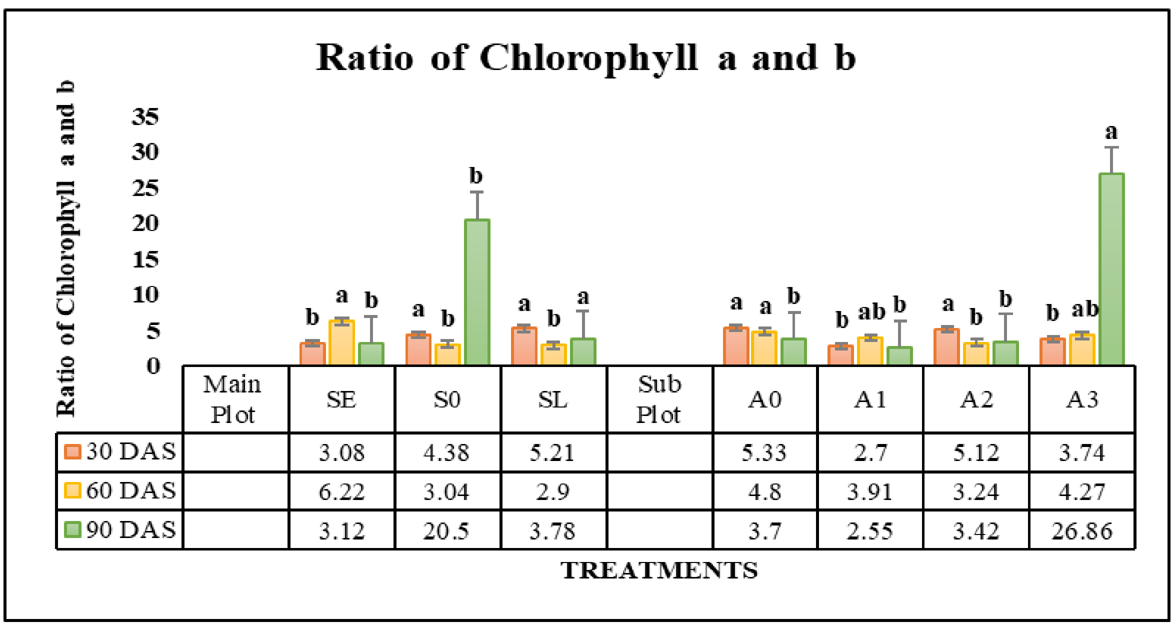


Figure 4.2.4.2b. Effect of sowing dates and agrochemicals treatments on ratio of chlorophyll a and b of maize at 30, 60, and 90 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.5 Total Carotenoid content (mg/g fresh weight): The impact of sowing dates and agrochemicals on the Total carotenoid content (mg/gm fresh weight) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS shown in (Table 4.2.5.1, 4.2.5.2 and Figure 4.2.5.1a, 4.2.5.2b). In 2022 and 2023, there was a significant difference in the percentage of Total carotenoid content (mg/gm fresh weight) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates and points of agrochemicals, it was estimated by comparing all the standards with the control. Thus, the percentage pattern in the Total carotenoid content (mg/gm fresh weight) was observed at 30, 60, and 90 DAS. In the year 2022, it was recorded that early sowing (SE) decreased the percentage by 71.48, and late sowing (SL) increased the rate by 5.47% as compared to the optimum sowing (S0) at 30 DAS. At 60, early (SE) and late sowing (SL) decreased the percentage by 22.51% and 31.85%, respectively, when compared with the optimum sowing (S0). A similar trend was found at 90 DAS: early and late sowing decreased the percentage by 19.71% and 34.77%, respectively, compared to the optimum sowing (S0). Among the applied agrochemicals, A2 showed the better result by increasing the percentage by 8.09%, 10.18%, and 7.07% at 30, 60 and 90 DAS, respectively, compared to the control (A0). The application of sodium nitroprusside also showed a better result by increasing the percentage by 16.01%, 5.50% and 11.09% at 30, 60 and 90 DAS, separately, compared to A3. In 2023, it was found that early sowing (SE) decreased the percentage by 71.14%, and late sowing increased the rate by 5.44% compared to the optimum sowing (S0) at 30 DAS. At 60 and 90 DAS, the early sowing and late sowing decreased the percentage by 22.46%, 31.78% and, 19.63%, 34.63%, respectively, compared to the optimum sowing (S0). Among the applied agrochemicals, the salicylic acid showed a better result by increasing the percentage by 9.32%,10.71% and 7.81% at 30, 60, and 90 DAS, respectively, compared with other applied agrochemicals A1 and A3. Within the complex domain of crop physiology, the aggregate carotenoid content is pivotal, offering significant elucidation regarding the plant's reaction to environmental stressors. Compared to the recommended planting timeframe, this study investigates the intricate dynamics of total carotenoids in crops exposed to untimely sowing, either in advance or delayed. Comprehending the scientific complexities associated with the total carotenoid content is crucial to elucidate the intricate interactions among environmental factors, timing of germination, and subsequent growth and reproductive processes. When seeds are planted before the optimal time, the resulting seedlings face various environmental stressors that significantly affect the overall carotenoid content. Late spring frosts present a considerable risk, which may hinder the process of carotenoid synthesis, affecting its optimal production. From a scientific perspective, it has been observed that being exposed to cold temperatures can have a disruptive effect on crucial physiological processes. This includes the metabolic pathways responsible for producing carotenoids, which are organic pigments. Consequently, the overall quantity and efficiency of total carotenoids can be influenced by such exposure. The effects of cold stress are evident in the decreased and inconsistent levels of entire carotenoid content in crops that are sown early, affecting their overall efficiency in photosynthesis and subsequent growth. On the other hand, sowing crops later than usual introduces specific environmental stress factors that impact the overall carotenoid content. The compressed duration of the growing season exerts substantial pressure on plants to accelerate their vegetative and reproductive growth. From a scientific standpoint, the shortened duration may reduce the overall carotenoid content as plants expedite their growth stages to allocate resources towards reproductive processes. Tangible limitations imposed by temporal constraints hinder the ability of crops to maximize their general carotenoid content. The scientific complexities of this process highlight the need for a careful equilibrium to attain an optimal overall carotenoid concentration in light of diverse environmental pressures linked to departure from the suggested timing for planting. The timing of sowing is considered a crucial element in scientific research on the total carotenoid content, as it determines the ideal conditions for the growth and development of crops. The temporal coincidence corresponds to advantageous ecological circumstances, encompassing factors such as temperature, soil moisture, and duration of daylight, all of which collectively contribute to the proficient synthesis of carotenoids. From a scientific perspective, this synchronization facilitates the timely activation of genetic and hormonal processes, resulting in a consistent and optimal accumulation of total carotenoid content. The suggested timing establishes the foundation for attaining an optimal photosynthetic equilibrium, a crucial factor in determining the crop's overall photosynthesis efficiency and yield potential. To address the effects of environmental stress on the general carotenoid content, a scientific investigation is undertaken to examine the influence of growth regulators. Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate carotenoid synthesis during unfavourable circumstances. From a scientific perspective, salicylic acid's activation of stress response genes has been found to improve a plant's capacity to endure environmental challenges. This, in turn, can potentially enhance the plant's overall carotenoid content more consistently and optimally. This strategic approach is especially pertinent for crops that are planted early, as it provides a scientific method to enhance the resilience of plants against the potential adverse impacts of late frosts on the synthesis of carotenoids. Furthermore, using sodium nitroprusside as a nitric oxide donor offers a scientific intervention to enhance the overall carotenoid content. When used carefully and deliberately, sodium nitroprusside impacts important physiological processes, including cell division and elongation, essential for producing carotenoids. From a scientific perspective, this application plays a role in determining the ideal level of total carotenoid content. This is particularly advantageous for crops planted late in the season and needs to promote both vegetative and reproductive growth despite the limitations of a shorter growing period. The precise application of these growth regulators demonstrates their capacity to regulate the physiological reactions of crops when confronted with environmental stressors linked to deviations from the recommended sowing schedule. In summary, the scientific investigation of the impact of environmental stress on the overall carotenoid content in crops provides a comprehensive comprehension of the complex interaction between timing, growth conditions, and the development of both vegetative and reproductive aspects (Alvarez et al., 2021; Kühling et al., 2023; Sabourifard et al., 2023; Jahangirlou et al., 2023; Yang et al., 2023; Liu et al., 2023; Kamkar et al., 2023; Fu et al., 2023; Li and Wang 2023; Affholder et al., 2023; Zhang et al., 2023). Crops that are sown early face the obstacle of late frosts, which hinder the achievement of an optimal total carotenoid content. On the other hand, crops planted late encounter the stress of a condensed growing season, which affects the synthesis of carotenoids. Based on scientific principles, determining the appropriate timing for sowing is crucial in creating the most favourable conditions for attaining an optimal total carotenoid content.

Table 4.2.5.1 Effect of treatments on total carotenoid content (mg/g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	**Total carotenoid content 2022**			**Total carotenoid content 2023**		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	10.94	38.90	41.54	11.14	39.00	41.74
S0 -Optimum sowing	38.37	50.20	51.74	38.57	50.30	51.94
SL -Late sowing	40.47	34.21	33.75	40.67	34.31	33.95
(Agrochemicals)						
A0- Control	28.66	40.50	40.47	28.86	40.60	40.67
A1-Sodium nitroprusside (250 µM/L)	33.25	42.73	44.96	33.45	42.83	45.16
A2-Salicylic acid (150mg/L)	31.35	44.85	43.65	31.55	44.95	43.85
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	26.44	36.33	40.31	26.64	36.43	40.51
CV (Sowing)	6.54	0.45	3.55	6.38	0.76	2.33
CV (Sowing date and agrochemical)	3.00	0.69	0.84	3.00	0.97	0.81
CD (Sowing)	2.17	0.35	1.12	2.15	0.38	1.25
CD (Agrochemicals)	0.89	0.39	0.34	0.83	0.28	0.42

Table 4.2.5.2 The interaction effect of treatments on total carotenoid content (mg/g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Total Carotenoid content-2022			Total Carotenoid content-2023		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
SEA0	6.95^{f} ±0.12	41.09^{f} ±0.10	41.53^{d} ±5.15	7.34f±0.46	41.42^{f}±0.41	44.75^{d}±1.26
SEA1	7.95^{h} ±2.67	43.04^{e} ±0.10	44.39^{d} ±1.11	8.34^{h}±2.36	43.33^{e}±0.27	44.66^{d}±1.18
SEA2	17.98^{h} ±2.80	39.05^{g} ±0.19	35.08^{gh} ±0.17	18.19^{h}±2.81	38.96^{g}±0.51	35.46^{gh}±0.43
SEA3	10.89 ^{g}±1.45	32.45^{j} ±0.14	41.94^{e} ±1.10	11.19^{g}±1.44	32.61^{j}±0.24	42.07^{e}±1.02
S0A0	36.58 ^{c}±0.22	45.62^{d} ±1.26	41.32^{e} ±0.14	36.64^{c}±0.18	45.71^{d}±1.24	41.67^{e}±0.28
S0A1	44.78 ^{a}±0.19	50.63^{b} ±0.12	55.96^{b} ±0.11	45.20^{a}±0.55	50.54^{b}±0.44	56.36^{b}±0.45
S0A2	45.65^{a} ±0.06	57.39^{a} ±0.05	58.06^{a} ±0.23	45.59^{a}±0.40	57.59^{a}±0.18	58.37^{a}±0.36
S0A3	26.48^{e} ±0.14	47.16^{c} ±0.12	51.66^{c} ±0.23	26.62^{e}±0.22	47.43^{c}±0.22	51.64^{c}±0.55
SLA0	31.44^{d} ±0.19	34.80^{i} ±0.19	35.32^{g} ±0.07	31.61^{d}±0.24	34.75^{i}±0.42	35.41^{g}±0.22
SLA1	47.03^{a} ±0.13	34.53^{i} ±0.13	34.53^{h} ±0.13	47.34^{a}±0.32	34.60^{i}±0.10	34.67^{h}±0.05
SLA2	41.46^{b} ±0.84	38.14^{h} ±0.17	37.82^{f} ±0.11	41.54^{b}±0.89	38.43^{h}±0.18	37.88^{f}±0.31
SLA3	41.98^{b} ±0.13	29.39^{k} ±0.17	27.35^{i} ±0.42	42.33^{b}±0.28	29.47^{k}±0.14	27.71^{i}±0.26
CV	3.00	0.69	0.84	3.00	0.97	0.81
CD	2.53	0.68	1.22	2.56	0.75	1.32

Figure 4.2.5.1a. Effect of sowing dates and agrochemicals treatments on total carotenoid content (mg/g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022

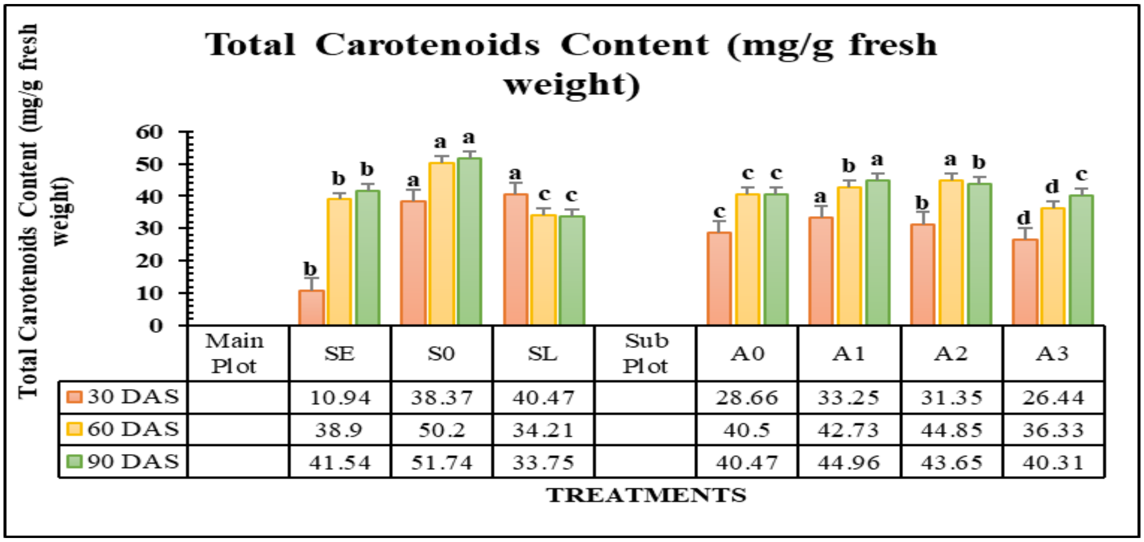
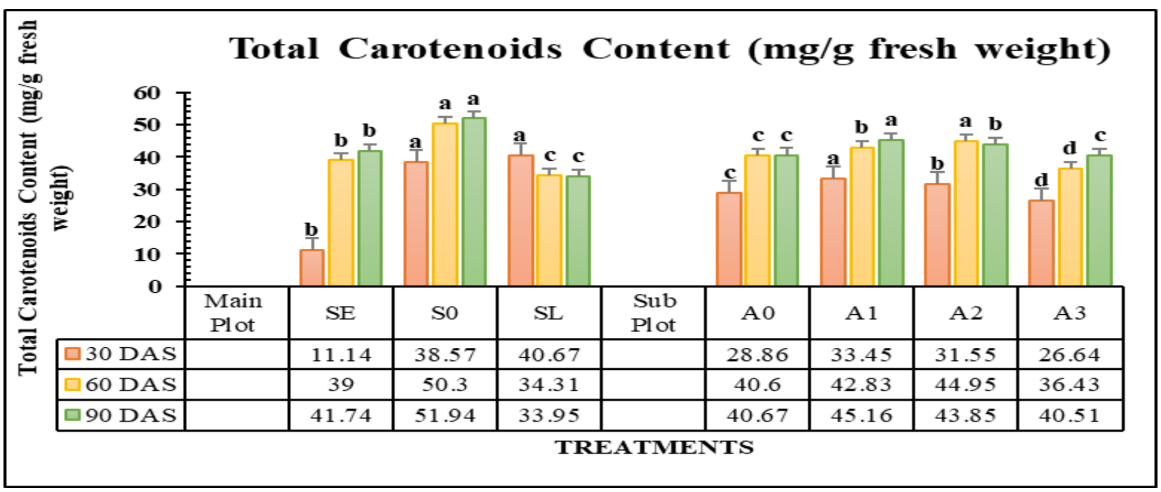


Figure 4.2.5.2b. Effect of sowing dates and agrochemicals treatments on total carotenoid content (mg/g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.6 Total Anthocyanin content (mg/g fresh weight): The impact of sowing dates and agrochemicals on the Total Anthocyanin content (mg/gm fresh weight) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS shown in (Table 4.2.6.1, 4.2.6.2, and Figure 4.2.6.1a, 4.2.6.2b). In 2022 and 2023, there was a significant difference in the percentage of Total Anthocyanin content (mg/gm fresh weight) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Total Anthocyanin content (mg/gm fresh weight) was observed at 30, 60, and 90 DAS. In 2022, it was found that early and late sowing decreased the percentage by 42.31% and 0.50%, respectively, compared to the optimum sowing (S0) at 30 DAS. At 60 DAS, the early and late sowing decreased the percentage by 73.06% and 32.33%, respectively, compared to the optimum sowing (S0). Similarly, at 90 DAS, the rate decreased in early (SE) and late Sowing (SL) by 44.02% and 36.41%, respectively. Among the applied agrochemicals, A3 had the highest percentage i.e., 58.03%, followed by A1 and A2, i.e., 11.38% and 5.45%, respectively, as compared to the optimum sowing (S0) at 30 DAS and AT 60, DAS A2 had the highest percentage i.e50.00% followed by A1 and A3, i.e., 24.873% and 3.29%, respectively, compared to the optimum sowing. Similar trends were observed at 90 DAS A2, which had the highest percentage, i.e. 26.03%, followed by A1 and A3, i.e., 24.56% and 7.89%, respectively, compared to the control (A0). In the year 2023, it was recorded that both early (SE) and late sowing (SL) decreased the percentage by 42.72% and 0.55%, respectively, as compared to the optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing (SE) decreased the percentage by 74.29% and late sowing (SL) by 32.44% as compared to the optimum sowing (S0). Similar trends were found at 90 DAS that early sowing (SE) and late sowing (SL) decreased the percentage by 44.21% and 36.57%, respectively ad compared to the control (A0). Among the applied agrochemicals, the salicylic acid showed a better result by increasing the percentage by 11.83%, 62.74%, and 35.20% at 30DAS, 60 DAS and 90 DAS, respectively, compared with the control (A0). Measuring total anthocyanin content is crucial, providing valuable insights into the plant's reaction to various environmental stressors. This study examines the intricate dynamics of total anthocyanins in crops exposed to untimely sowing before or after the recommended planting timeframe. Comprehending the scientific complexities associated with the entire anthocyanin content is imperative to elucidate the intricate interactions among environmental factors, timing of germination, and subsequent growth and reproductive processes. When seeds are planted before the optimal time, the resulting seedlings are exposed to various environmental stressors that significantly affect the overall amount of anthocyanin present. Late spring frosts present a significant risk, potentially hindering the optimal anthocyanin synthesis process. From a scientific perspective, it has been observed that being exposed to cold temperatures can interfere with crucial physiological processes. This includes the metabolic pathways responsible for producing anthocyanins, which are compounds that contribute to the overall quantity and effectiveness of total anthocyanins. The repercussions of cold stress are evident in the diminished and inconsistent total anthocyanin levels observed in crops planted early, affecting their overall photosynthetic efficiency and subsequent growth. On the other hand, sowing crops later than usual introduces specific environmental stress factors that impact the general content of anthocyanins. The compressed duration of the growing season exerts substantial pressure on plants to accelerate their vegetative and reproductive growth. From a scientific standpoint, the shortened course may reduce the overall anthocyanin content as plants expedite their growth stages to allocate resources towards reproductive processes. Tangible limitations imposed by time constraints hinder the ability of crops to maximize their general anthocyanin content. The scientific complexities of this process highlight the importance of maintaining a precise equilibrium to attain an optimal overall anthocyanin concentration despite diverse environmental pressures resulting from deviations from the suggested timing for planting. The timing of sowing is considered a crucial factor in scientific research on the total anthocyanin content, as it helps determine the ideal conditions for crop growth and development(Alvarez et al., 2021; Kühling et al., 2023; Sabourifard et al., 2023; Jahangirlou et al., 2023; Yang et al., 2023; Liu et al., 2023; Kamkar et al., 2023). The synchronization corresponds to advantageous ecological circumstances, encompassing factors such as temperature, soil moisture, and duration of daylight, all of which contribute to the practical synthesis of anthocyanins. From a scientific perspective, this synchronization facilitates the timely activation of genetic and hormonal processes, resulting in a consistent and optimal accumulation of total anthocyanin content. The suggested timing establishes the foundation for attaining an optimal photosynthetic equilibrium, a crucial factor in determining the crop's overall photosynthetic efficiency and potential yield. To address the consequences of environmental stress on the general anthocyanin content, a scientific investigation is undertaken to examine the influence of growth regulators. Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate the synthesis of anthocyanins in the presence of unfavourable environmental conditions. From a scientific perspective, salicylic acid's activation of stress response genes has been found to improve a plant's capacity to endure ecological difficulties. This process could enhance the overall anthocyanin content more consistently and optimally. This strategic approach is especially pertinent for crops that are planted early, as it provides a scientific method to enhance the resilience of plants against the potential negative impacts of late frosts on the synthesis of anthocyanins. Furthermore, using sodium nitroprusside as a nitric oxide donor offers a scientific approach to enhance the overall anthocyanin content. When sodium nitroprusside is used carefully and deliberately, it impacts essential physiological processes, including cell division and elongation, which are fundamental to the production of anthocyanins. From a scientific perspective, this application plays a role in determining the ideal total anthocyanin content, which is particularly advantageous for crops that are planted late and need to promote both vegetative and reproductive growth within a limited growing season. The intricate utilization of these growth regulators demonstrates their capacity to regulate the physiological reactions of crops when confronted with environmental stressors that arise from deviations in recommended sowing timing. The scientific investigation of the impact of environmental stress on the overall anthocyanin content in crops provides a comprehensive comprehension of the complex interaction between timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops that are sown early face the obstacle of late frosts, which hinder the achievement of an optimal total anthocyanin content. The investigation into the total anthocyanin content and the impact of environmental stressors in agricultural settings provides valuable insights into the complex mechanisms regulating crop development's vegetative and reproductive phases (Wang et al., 2023).

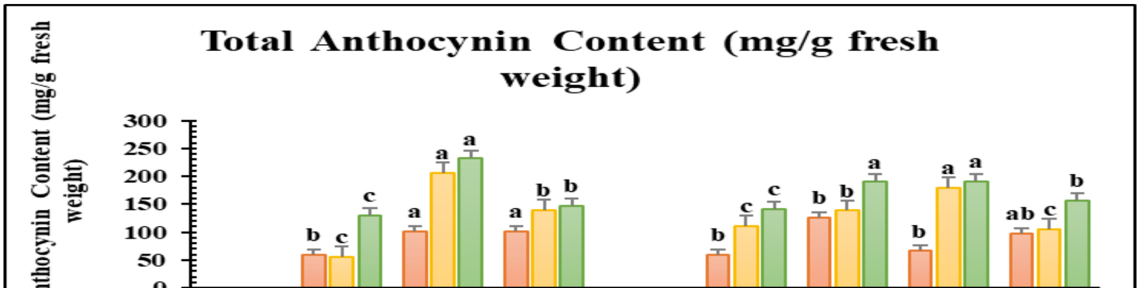
Table 4.2.6.1 Effect of treatments on total anthocyanin content (mg/g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Total Anthocyanin content-2022			Total Anthocyanin content-2023		
At different Interval	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
(Sowing Date)						
SE -Early sowing	58.66	55.49	129.69	57.69	54.83	128.70
S0 -Optimum sowing	101.69	205.99	231.69	100.72	205.34	230.71
SL -Late sowing	101.13	139.38	147.31	100.16	138.72	146.33
(Agrochemicals)						
A0- Control	59.12	110.94	141.31	58.15	110.29	140.33
A1-Sodium nitroprusside (250 µM/L)	126.10	138.38	189.85	125.13	137.72	188.87
A2-Salicylic acid (150mg/L)	66.00	180.14	190.73	65.03	179.49	189.74
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	97.42	105.01	156.36	96.45	104.36	155.38
CV (Sowing)	68.27	18.50	5.46	6.38	0.76	2.33
CV (Sowing date and agrochemical)	69.48	14.88	4.92	3.00	0.97	0.81
CD (Sowing)	67.44	28.01	10.49	68.21	36.21	15.25
CD (Agrochemicals)	59.98	19.68	8.25	49.52	20.25	9.56

Table 4.2.6.2 The interaction effect of treatments on total anthocyanin content (mg/g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Total Anthocyanin content-2022			Total Anthocyanin content-2023		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
SEA0	39.90^{c}±3.56	14.73^{d} ±2.59	118.41^{g} ±5.69	38.93^{c}±3.56	13.96^{d}±2.51	117.43^{g}±5.69
SEA1	52.69^{bc}±7.10	38.70 ^{d}±26.86	144.36^{e} ±6.13	51.72^{bc}±7.10	25.05^{d}±4.70	143.37^{e}±6.13
SEA2	72.66^{abc}±18.81	114.89^{c} ±6.31	129.63^{fg}±3.93	82.99^{abc}±2.14	114.24c±6.31	128.64^{fg}±3.93
SEA3	69.38 ^{abc}±3.16	18.82^{d} ±3.22	126.35^{fg} ±4.43	68.41^{abc}±3.16	92.33^{d}±5.61	125.37^{fg}±4.43
S0A0	83.79^{abc} ±6.31	183.70^{b} ±53.75	174.88^{d} ±20.32	82.82^{abc}±6.31	220.98^{b}±11.99	183.79^{d}±5.15
S0A1	54.26^{a} ±7.45	244.84^{a} ±3.45	284.13^{a} ±7.37	51.62^{a}±4.56	244.19^{a}±3.45	283.14^{a}±7.37
S0A2	58.58^{bc}±2.47	241.90^{a} ±4.94	257.61^{b} ±3.45	57.61^{bc}±2.47	241.24^{a}±4.94	256.63^{b}±3.45
S0A3	93.61^{abc} ±4.94	153.52^{bc} ±6.00	210.15^{c} ±5.47	92.64^{abc}±4.94	152.86^{bc}±6.00	209.17^{c}±5.47
SLA0	53.67^{bc} ±4.09	122.16^{c} ±2.02	130.63^{efg} ±9.32	52.70^{bc}±4.09	121.51^{c}±2.02	129.65^{efg}±9.32
SLA1	154.82^{ab} ±5.04	131.59^{c} ±5.04	141.08^{ef} ±4.64	153.85^{ab}±5.04	130.93^{c}±5.04	140.10^{ef}±4.64
SLA2	66.76 ^{abc}±5.20	183.63^{b} ±7.24	184.94^{d} ±9.54	65.79^{abc}±5.20	182.98^{b}±7.24	183.96^{d}±9.54
SLA3	129.28^{abc} ±4.43	120.13^{c} ±3.00	132.58^{efg} ±2.61	128.31^{abc}±4.43	119.48^{c}±3.00	131.60^{efg}±2.61
CV	69.48	14.88	4.92	3.00	0.97	0.81
CD	11.53	40.32	16.18	98.52	40.56	16.08

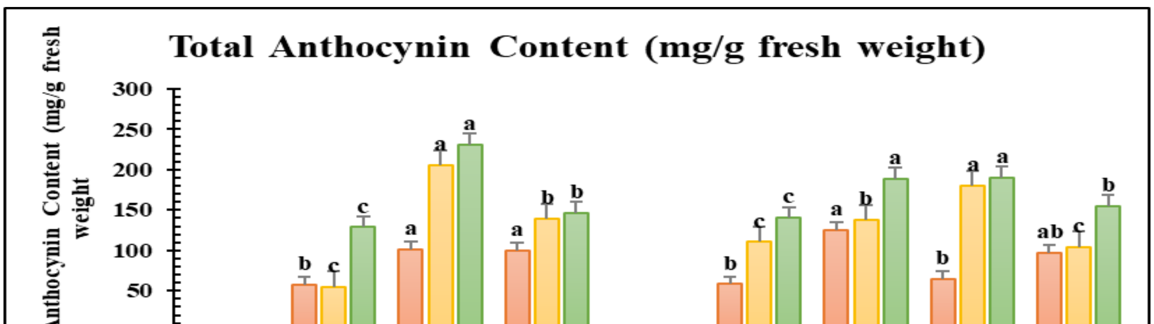
Figure 4.2.6.1a. Effect of sowing dates and agrochemicals treatments on total anthocyanin content (mg/g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		58.66	101.69	101.13		59.12	126.1	66	97.42
60 DAS		55.49	205.99	139.38		110.94	138.38	180.14	105.01
90 DAS		129.69	231.69	147.31		141.31	189.85	190.73	156.36

TREATMENTS

Figure 4.2.6.2b. Effect of sowing dates and agrochemicals treatments on total anthocyanin content (mg/g fresh weight) of maize at 30, 60, and 90 DAS during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		57.69	100.72	100.16		58.15	125.13	65.03	96.45
60 DAS		54.83	205.34	138.72		110.29	137.72	179.49	104.36
90 DAS		128.7	230.71	146.33		140.33	188.87	189.74	155.38

TREATMENTS

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.7 Total Soluble Sugar (microgram/ml): The impact of sowing dates and agrochemicals on the Total Soluble Sugar (microgram/ml) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30DAS, 60DAS, and 90 DAS shown in (Table 4.2.7.1, 4.2.7.2, 4.20 and Figure 4.2.7.1a, 4.2.7.2b). In 2022 and 2023, there was a significant difference in the percentage of total Soluble Sugar (microgram/ml) sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals; it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Total Soluble Sugar (microgram/ml) was observed at 30, 60, and 90 DAS. In the year 2022, it was found that early sowing (SE) decreased the percentage by 83.49%, and late sowing (SL) increased the rate by 7.71% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing (SE) increased the percentage by 67.68%, and the late sowing decreased by 17.64%, respectively. In the case of 90 DAS, the early sowing (SE) reduced the percentage by 25.60% and late sowing (SL) decreased the rate by 13.05% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 increased the percentage by 13.32%, A2 increased by 4.66%, and A3 increased the rate by 1.13% compared to control (A0) at 30 DAS. At 60 DAS, the A1, A2 and A3 increased the speed by 19.41%, 33.46%, and 9.68%, respectively, compared to the control. In the case of 90 DAS, the percentage increased in A1, A2, and A3 by 28.55%, 42.69% and 22.49%, respectively, compared to the control (A0). In the year 2023, the early sowing (SE) decreased the percentage by 83.34% and late sowing (SL) increased the percentage by 7.70% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, early sowing (SE) increased the rate by 67.31%, and late sowing decreased by 17.54%. In the case of 90 DAS, the early sowing (SE) reduced the percentage by 25.48% and late sowing (SL) decreased the rate by 12.99 % as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 increased the percentage by 13.28%, A2 by 5.27 %, and A3 by 2.58% compared to control (A0) at 30 DAS. At 60 DAS, the A1, A2 and A3 increased the rate by 19.30%, 39.74% and 13.47% respectively compared to the control. In the case of 90 DAS, the percentage increased in A1, A2 and A3 by 28.35%, 54.50% and 34.59%, respectively, compared to the control (A0). Within the complex domain of crop physiology, the measurement of total sugar content emerges as a pivotal parameter, offering valuable insights into the plant's reaction to various environmental stressors (Hongzhang et al., 2023; Yuanda Zhang et al., 2023; Zhang et al., 2023). This scientific investigation examines the intricate dynamics of total sugars in crops exposed to untimely sowing, either in advance or delayed, compared to the prescribed planting timetable. Comprehending the scientific complexities associated with the overall sugar content is imperative to elucidate the intricate relationship between environmental factors, timing of germination, and subsequent growth and reproductive processes. When seeds are sown before the optimal time, the resulting seedlings are exposed to various environmental stressors that substantially affect the overall sugar content. Late spring frosts present a significant risk, which can potentially hinder the process of optimal sugar synthesis. From a scientific perspective, it has been observed that exposure to cold temperatures can have a disruptive effect on crucial physiological processes. This disruption affects the metabolic pathways responsible for sugar production, impacting total sugars' overall quantity and efficiency. The repercussions of cold stress are evident in the diminished and irregular total sugar levels observed in crops that are sown early, affecting their overall photosynthetic efficiency and subsequent growth. On the other hand, delayed sowing of crops introduces specific environmental stress factors that impact the overall sugar content. The compressed duration of the growing season exerts considerable pressure on plants to accelerate their vegetative and reproductive growth. From a scientific standpoint, the shortened duration could decrease overall sugar content as plants expedite their growth stages to allocate resources towards reproductive processes. Tangible limitations imposed by time constraints hinder the ability of crops to maximize their general sugar content. The scientific complexities of this process highlight the need for a careful equilibrium to attain an optimal total sugar content amidst diverse environmental stressors linked to departure from suggested sowing schedules. The timing of sowing is considered a crucial element in scientific research on total sugar content, as it determines the ideal conditions for crop growth and development. The temporal occurrence coincides with advantageous ecological circumstances, encompassing temperature, soil moisture, and daylight duration, collectively contributing to sugar's practical synthesis. From a scientific perspective, this synchronizations facilitates the timely activation of genetic and hormonal processes, ultimately attaining uniform and optimal total sugar content. The suggested timing establishes the foundation for attaining an optimal photosynthetic equilibrium, a crucial factor in determining the crop's overall photosynthetic efficiency and potential yield. To address the effects of environmental stress on the general sugar content, a scientific investigation is undertaken to examine the influence of growth regulators. Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate sugar synthesis during unfavourable circumstances. From a scientific perspective, activating stress response genes by salicylic acid can improve a plant's capacity to endure environmental challenges, which may result in a more consistent and optimal total sugar content. This strategic approach is especially pertinent for crops that are planted early, as it provides a scientific method to enhance the resilience of plants against the potential negative impacts of late frosts on the process of sugar synthesis. In addition, using sodium nitroprusside as a nitric oxide donor offers a scientific intervention to optimise the overall sugar content. When used carefully and deliberately, sodium nitroprusside impacts vital physiological processes, including cell division and elongation, essential for sugar production. From a scientific perspective, this application plays a role in determining the ideal amount of total sugar content. It is particularly advantageous for crops planted late in the season and needs to promote both vegetative and reproductive growth despite the limitations of a shorter growing period. The intricate utilisation of these growth regulators demonstrates their capacity to regulate the physiological reactions of crops when confronted with environmental stressors that arise from deviations in recommended sowing timing (Wang et al., 2023; Yuanda Zhang et al., 2023). The scientific investigation of the impact of environmental stress on the overall sugar content in crops provides a comprehensive comprehension of the complex interactions between timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops planted early face the obstacle of late frosts, which hinder the attainment of an optimal total sugar content. On the other hand, crops that are planted late encounter the challenge of a shortened growing season, which affects the process of sugar synthesis. Establishing optimal conditions for achieving an ideal total sugar content is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions for improving the resilience of crops. These interventions can affect the total sugar content and influence the crop's overall photosynthetic efficiency and yield potential. Investigating total sugar content and environmental stressors in the agricultural domain provides valuable insights into the complex mechanisms regulating crop development's vegetative and reproductive phases.

Table 4.2.7.1 Effect of treatments on total soluble sugar of maize (microgram/ml) of maize at 30, 60, and 90 DAS during spring season 2023 and 2023

Treatments	Total soluble sugar-2022			Total soluble sugar-2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	8.94	61.69	31.35	9.04	61.89	31.55
S0 -Optimum sowing	54.17	36.79	42.14	54.27	36.99	42.34
SL -Late sowing	58.35	30.30	36.64	58.45	30.50	36.84
(Agrochemicals)						
A0- Control	38.58	36.31	28.33	38.68	36.51	28.53
A1-Sodium nitroprusside (250 µM/L)	43.72	43.36	36.42	43.82	43.56	36.62
A2-Salicylic acid (150mg/L)	40.62	50.82	43.88	40.72	51.02	44.08
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	39.04	41.23	38.20	39.68	41.43	38.40
CV (Sowing)	5.00	5.72	6.36	69.03	18.59	5.49
CV (Sowing date and agrochemical)	8.19	13.36	14.17	70.27	14.95	4.94
CD (Sowing)	2.29	2.78	2.64	3.25	2.65	3.52
CD (Agrochemicals)	3.28	5.68	5.15	3.35	5.55	5.25

Table 4.2.7.2 The interaction effect of treatments on total soluble sugar of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Total soluble sugar-2022			Total soluble sugar-2023		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
SEA0	7.15^{f}±0.68	55.71^{b}±4.68	20.28^{f}±0.71	6.63^{f}±1.60	55.91^{b}±4.68	20.48^{f}±0.71
SEA1	14.57^{e}±9.18	57.46^{ab}±0.48	27.65^{ef}±0.33	14.67^{e}±9.18	57.66^{ab}±0.48	27.85^{ef}±0.33
SEA2	7.29^{f}±0.96	67.01^{a}±1.77	36.20^{cde}±0.68	7.71^{f}±1.35	67.21^{a}±1.77	36.40^{cde}±0.68
SEA3	7.29^{f}±0.99	66.61^{a}±1.46	41.30^{bc}±0.49	7.39^{f}±0.99	66.81^{a}±1.46	41.50^{bc}±0.49
S0A0	53.94^{cd}±2.43	24.56^{ef}±7.46	32.77^{cde}±7.67	54.04^{cd}±2.43	24.76^{ef}±7.46	32.97^{cde}±7.67
S0A1	57.14^{abc}±1.13	37.06^{cd}±4.38	44.69^{ab}±6.24	57.24^{abc}±1.13	37.26^{cd}±4.38	44.89^{ab}±6.24
S0A2	54.35^{bcd}±2.14	44.15^{c}±3.92	49.68^{a}±2.49	54.45^{bcd}±2.14	44.35^{c}±3.92	49.88^{a}±2.49
S0A3	51.29^{d}±0.75	41.43^{c}±13.28	41.43^{abc}±8.70	51.39^{d}±0.75	46.11^{c}±5.54	41.63^{abc}±8.70
SLA0	54.65^{bcd}±4.31	28.66^{de}±4.10	31.96^{de}±0.89	54.75^{bcd}±4.31	28.86^{de}±4.10	32.16^{de}±0.89
SLA1	59.47^{ab}±1.53	35.58^{cd}±5.35	36.95^{bcd}±8.83	59.57^{ab}±1.53	35.78^{cd}±5.35	37.15^{bcd}±8.83
SLA2	60.74^{a}±0.50	41.31^{c}±0.51	45.79^{ab}±0.83	60.84^{a}±0.50	41.51^{c}±0.51	45.99^{ab}±0.83
SLA3	58.57^{abc}±0.40	15.67^{f}±1.23	31.89^{de}±0.64	58.67^{abc}±0.40	15.87^{f}±1.23	32.09^{de}±0.64
CV	8.19	13.36	14.17	70.27	14.95	4.94
CD	5.40	8.94	8.14	5.60	8.65	8.24

Figure 4.2.7.1a. Effect of sowing dates and agrochemicals treatments on total soluble sugar of maize (microgram/ml) of maize at 30, 60, and 90 DAS during spring season 2022

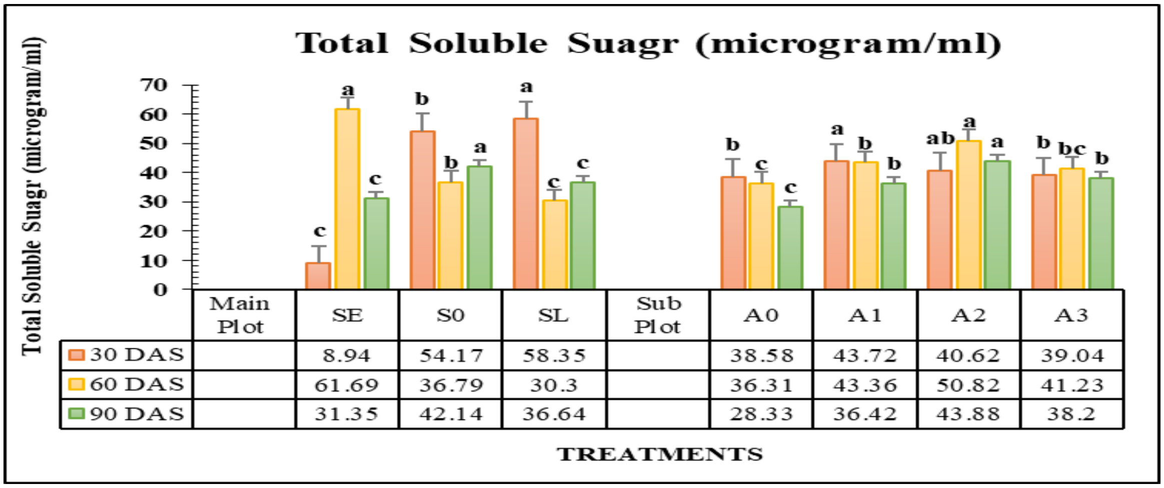
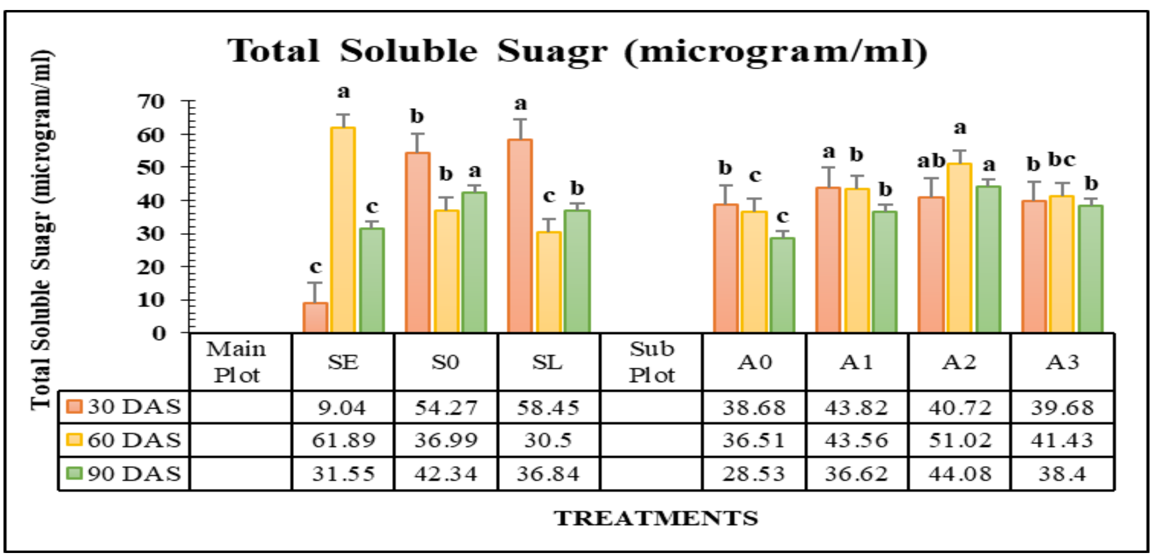


Figure 4.2.7.2b. Effect of sowing dates and agrochemicals treatments on total soluble sugar of maize (microgram/ml) of maize at 30, 60, and 90 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.8 Total Soluble Protein (microgram/ml): The impact of sowing dates and agrochemicals on the Total Soluble Protein (microgram/ml) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90. DAS is shown in (Table 4.2.8.1 4.2.8.2, 4.2.8.3, and 4.2.8.4 and Figure 4.2.8.1a, 4.2.8.2b). In 2022 and 2023, there was a significant difference in the percentage of Total Soluble Protein (microgram/ml) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals; it was calculated by comparing all the mean with control. Thus, the percentage pattern in Total Soluble Protein (microgram/ml) was observed at 30, 60, and 90 DAS. In the year 2022, it was found that early sowing (SE) decreased the percentage by 73.13%, and late sowing (SL) increased the percentage by 34.57% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, early sowing (SE) increased the percentage by 31.98%, and late sowing decreased by 35.38%, respectively. In the case of 90 DAS, the early sowing (SE) increased the percentage by 20.16%, and the late sowing (SL) decreased the percentage by 28.81% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 increased the percentage by 15.67%, A2 increased by 97.06%, and A3 increased the percentage by 12.77% as compared to control (A0) at 30 DAS. At 60 DAS, the A1, A2, and A3 they increased the percentage by 7.88%, 3.07% and 8.43%, respectively, compared to the control. In the case of 90 DAS, the percentage increased in A1, A2 and A3 by 22.22%, 21.21% and 9.80%, respectively, compared to the control (A0). In the year 2023, the early sowing (SE) decreased the percentage by 71.24%, and the late sowing (SL) increased the percentage by 33.67% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, early sowing (SE) increased the percentage by 29.65%, and late sowing decreased by 32.85%, respectively. In the case of 90 DAS, the early sowing (SE) increased the percentage by 15.05%, and late sowing (SL) decreased the percentage by 21.51% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 increased the percentage by 15.04%, A2 increased by 10.07%, and A3 increased the percentage by 26.01% as compared to control (A0) at 30 DAS. At 60 DAS, the A1, A2 and A3 increased the percentage by 7.56%, 3.18% and 8.36%, respectively, in comparison to the control. In the instance of DAS 90, the percentage increased in A1, A2 and A3 by 17.82%, 20.79% and 9.90%, respectively, compared to the control (A0). The complex network of environmental stressors impacting the overall concentration of soluble proteins in crops unveils a sophisticated interaction among multiple factors, with particular emphasis on the timing of planting. Sowing seeds earlier or later than the recommended schedule poses distinct challenges that significantly impact plant synthesis of soluble proteins. Comprehending these fluctuations is imperative in deciphering the intricate correlation between environmental stressors, the timing of germination, and the subsequent growth and reproductive processes of crops. Sowing seeds at an early stage exposes the emerging seedlings to a wide range of environmental stressors, significantly impacting total soluble protein production. Late spring frosts are stressors that can pose a considerable threat, as they can potentially disrupt the delicate equilibrium of protein production. Low temperatures hinder essential physiological mechanisms, such as the metabolic pathways associated with the synthesis of proteins. This phenomenon has a measurable effect on soluble proteins' overall quantity and efficiency. The impact of cold stress is apparent in crops planted early, as it decreases soluble protein content and disrupts their photosynthetic efficiency, thereby impeding their subsequent growth. On the other hand, sowing crops later than usual introduces a distinct array of environmental stress factors that impact the overall concentration of soluble proteins in the crops. The compressed duration of the growing season places considerable stress on plants, compelling them to accelerate both their vegetative and reproductive growth. In the given situation, the condensed period may potentially reduce the overall concentration of soluble proteins. This can occur as plants expedite their growth stages to allocate resources towards reproductive processes. Tangible time constraints hinder the ability of crops to maximize their overall soluble protein content. This underscores the importance of maintaining an optimal soluble protein content amidst fluctuating environmental stressors that arise from deviations in recommended sowing timing (Wang et al., 2023; Zhang et al., 2023; Paudel et al., 2023). The timing of sowing, as instructed, is of utmost importance in the scientific study of total soluble protein content, as it establishes the most favourable conditions for the growth and development of crops. The temporal coincidence corresponds to advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which collectively contribute to the optimal process of protein synthesis. The synchronization method facilitates the prompt activation of genetic and hormonal mechanisms, resulting in a consistent and optimal total soluble protein content level. The suggested timing establishes the foundation for attaining an optimal photosynthetic equilibrium, a crucial factor in determining the crop's overall development and efficiency. A systematic approach is employed to investigate the influence of growth regulators to address the consequences of environmental stress on the overall concentration of soluble proteins. Salicylic acid, well-known for its role in plant defence mechanisms, can be utilized to regulate protein synthesis during unfavourable circumstances. This strategic approach becomes especially pertinent for crops that are sown early, as it provides a method to enhance the resilience of plants against the potential adverse impacts of late frosts on the process of protein synthesis. Salicylic acid's activation of stress response genes has been found to enhance the plant's capacity to endure environmental challenges, which may contribute to a more consistent and optimal total soluble protein content. In addition, using sodium nitroprusside as a nitric oxide donor presents an intervention strategy to optimise the overall range of soluble proteins. When sodium nitroprusside is used carefully and deliberately, it impacts vital physiological processes, including cell division and elongation, which are essential for the production of proteins. This application aids in achieving an ideal level of total soluble protein content, which is particularly advantageous for crops that are sown late and need to enhance both vegetative and reproductive growth despite a shorter growing season. The intricate utilization of these growth regulators exemplifies their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from suggested sowing timing. The investigation into the impact of environmental stress on the overall concentration of soluble proteins in crops provides a comprehensive comprehension of the complex interaction between factors such as timing, growth conditions, and the development of both vegetative and reproductive components. Crops that are sown early face the obstacle of late frosts, which hinder the attainment of an optimal total soluble protein content. On the other hand, crops that are planted late encounter the stress of a condensed growing season, affecting the protein synthesis process. Establishing optimal conditions for achieving an ideal total soluble protein content is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and Sodium nitroprusside into scientific methodologies presents strategic interventions to improve crops' resilience.

These interventions have the potential to impact the overall growth and productivity of the crop by influencing the content of total soluble proteins. This scientific investigation illuminates the environmental stress factors encountered by crops. It offers a framework for deliberate interventions to address these challenges and enhance the concentration of soluble proteins for resilient crop growth (Pal et al., 2023; Singh et al., 2023; Dharmendra Kumar et al., 2023; Zhu et al., 2023; Kráľová and Jampílek 2023).

Table 4.2.8.1 Effect of treatments on total soluble protein of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Total soluble protein-2022			Total soluble protein-2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	1.01	5.45	1.78	1.11	5.55	1.98
S0 -Optimum sowing	3.76	1.30	0.59	3.86	1.40	0.79
SL -Late sowing	5.06	0.84	0.42	5.16	0.94	0.62
(Agrochemicals)						
A0- Control	2.36	2.41	0.81	2.46	2.51	1.01
A1-Sodium nitroprusside (250 µM/L)	2.73	2.60	0.99	2.83	2.70	1.19
A2-Salicylic acid (150mg/L)	5.01	2.49	1.02	5.11	2.59	1.22
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	3.00	2.62	0.91	3.10	2.72	1.11
CV (Sowing)	4.90	6.38	4.17	4.76	6.13	3.43
CV (Sowing date and agrochemical)	3.69	5.56	6.01	3.59	5.35	4.95
CD (Sowing)	0.18	0.18	0.04	0.17	0.19	0.03
CD (Agrochemicals)	0.12	0.13	0.05	0.15	0.16	0.04

Table 4.2.8.2 Interaction effect of treatments on total soluble protein of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Total soluble protein-2022			Total soluble protein-2023		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
SEA0	0.99^{g} ±0.05	4.41^{d} ±0.42	1.65^{c}±0.05	1.09^{g}±0.05	4.51^{d}±0.42	1.85^{c}±0.05
SEA1	0.89^{g}±0.16	4.74^{c} ±0.03	1.93^{a} ±0.08	0.99^{g}±0.16	4.84^{c}±0.03	2.13^{a}±0.08
SEA2	1.28^{f}±0.28	5.51^{b} ±0.14	1.74^{bc} ±0.12	1.38^{f}±0.28	5.61^{b}±0.14	1.94^{bc}±0.12
SEA3	0.91^{g} ±0.23	7.14^{a} ±0.08	1.81^{b} ±0.06	1.01^{g}±0.23	7.24^{a}±0.08	2.01^{b}±0.06
S0A0	4.10^{c} ±0.09	2.04^{e} ±0.11	0.46^{f} ±0.06	4.20^{c}±0.09	2.14^{e}±0.11	0.66^{f}±0.06
S0A1	3.14^{d} ±0.05	2.02^{e} ±0.07	0.35^{g} ±0.05	3.24^{d}±0.05	2.12^{e}±0.07	0.55^{g}±0.05
S0A2	6.81^{c}±0.17	1.04^{fg} ±0.08	0.86^{d} ±0.06	6.91^{b}±0.17	1.14^{fg}±0.08	1.06^{d}±0.06
S0A3	1.01^{g} ±0.06	0.13^{i} ±0.03	0.72^{e} ±0.05	1.11^{g}±0.06	0.23^{i}±0.03	0.92^{e}±0.05
SLA0	2.02^{e} ±0.13	0.79^{gh} ±0.06	0.33^{g} ±0.07	2.12^{e}±0.13	0.89^{gh}±0.06	0.53^{g}±0.07
SLA1	4.19^{c} ±0.12	1.05^{f} ±0.07	0.70^{e} ±0.06	4.29^{c}±0.12	1.15^{f}±0.07	0.90^{e}±0.06
SLA2	6.96^{ab} ±0.09	0.92^{fg} ±0.10	0.48^{f} ±0.05	7.06^{ab}±0.09	1.02^{fg}±0.10	0.68^{f}±0.05
SLA3	7.10^{a} ±0.07	0.60^{h} ±0.14	0.21^{h} ±0.05	7.20^{a}±0.07	0.70^{h}±0.14	0.41^{h}±0.05
CV	3.69	5.56	6.01	3.59	5.35	4.95
CD	0.25	0.27	0.09	0.28	0.29	0.08

Figure 4.2.8.1a. Effect of sowing dates and agrochemicals treatments on total soluble protein of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022

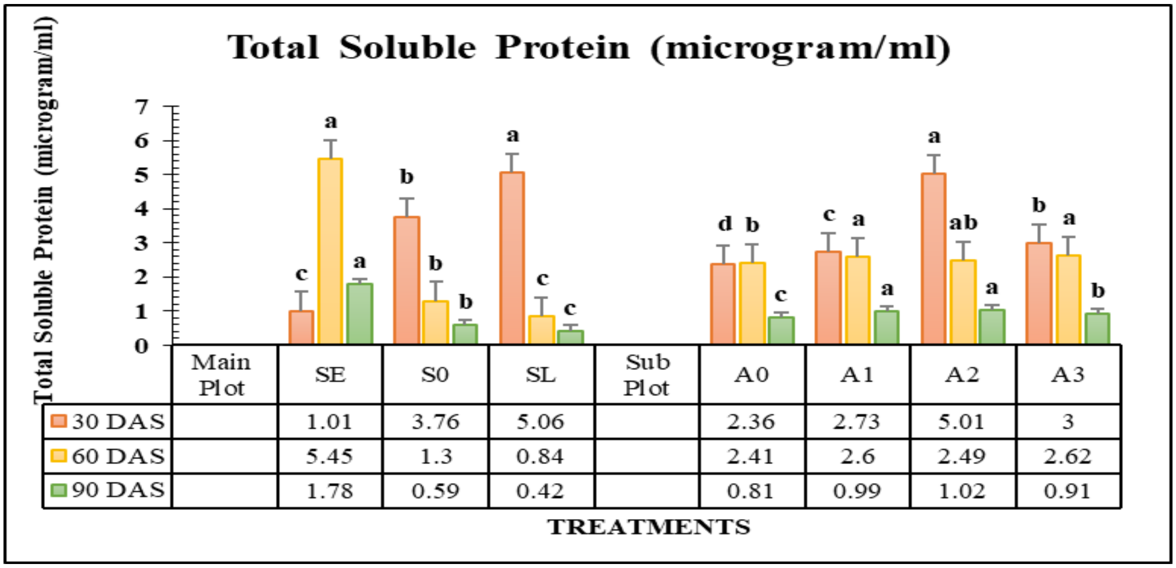
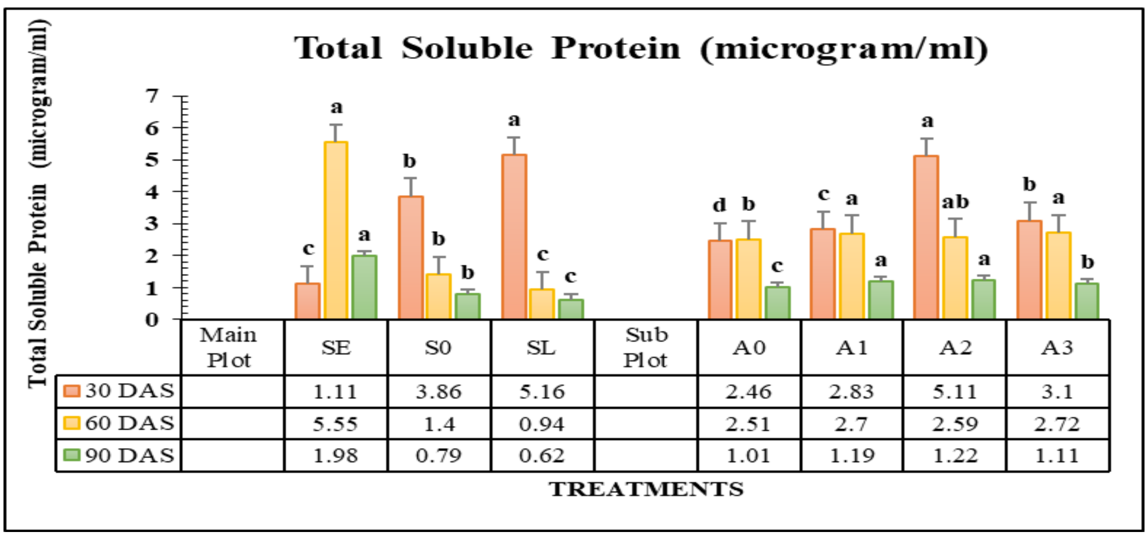


Figure 4.2.8.2b. Effect of sowing dates and agrochemicals treatments on total soluble protein of maize at 30, 60, and 90 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.9 Total Amylose (%): The impact of sowing dates and agrochemicals on the Total Amylose (%) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30DAS, 60DAS, and 90 DAS (Table 4.2.9.1, 4.2.9.2, 4.2.9.3, 4.2.9.4 and Figure 4.2.9.1a, 4.2.9.2b). In 2022 and 2023, there was a significant difference in the percentage of Total Amylose (%) sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals; it was estimated by comparing all the standards with control. Thus, the percentage pattern in Total Amylose (%) was observed at 30, 60, and 90 DAS. In the year 2022, it was found that early sowing (SE) decreased the percentage by 58.12%, and late sowing (SL) decreased the rate by 22.08% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing (SE) reduced the percentage by 56.81%, and the late sowing decreased by 59.67%, respectively. In the case of 90 DAS, the early sowing (SE) increased the percentage by 69.36%, and the late sowing (SL) decreased the rate by 31.48% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 decreased the percentage by 13.74%, A2 increased by 19.12%, and A3 decreased by 5.03% compared to control (A0) at 30 DAS. At 60 DAS, the A1, A2, and A3 they increased the percentage by 30.91%, 10.99%, and 34.65%, respectively, in comparison to the control. In the instance of 90 DAS, the rate increased by 43.66%, 26.14%, and 11.26%, respectively, in A1, A2, and A3, compared to the control (A0). In the year 2023, the early sowing (SE) decreased the percentage by 55.31% and late sowing (SL) reduced the rate by 21.01% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, early sowing (SE) decreased the percentage by 55.28%, and late sowing decreased by 58.62%, respectively. In the case of 90 DAS, the early sowing (SE) increased the rate by 63.92% and late sowing (SL) decreased the speed by 29.02% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 decreased the percentage by 12.86%, A2 increased by 15.43%, and A3 reduced the rate by 5.78% compared to control (A0) at 30 DAS. At 60 DAS, the A1, A2, and A3 they have increased the percentage by 31.33%, 13.73%, and 80.64%, respectively, compared to the control. In the case of 90 DAS, the rate increased in A1, A2, and A3 by 39.91%, 34.33%, and 14.16%, respectively, compared to the control (A0). Within the complex realm of crop physiology, the overall amylose content is a significant parameter, providing valuable insights into how plants react to various environmental stressors. This study examines the intricate interactions of total amylose content in crops when subjected to untimely sowing before or after the recommended planting schedule. Comprehending the fluctuations in overall amylose content is crucial for elucidating the influence of environmental factors, timing of germination, and subsequent growth and reproductive processes. The practice of sowing seeds at an early stage exposes nascent seedlings to various environmental stressors, which substantially affect the overall amylose content. Late spring frosts present a significant risk, potentially disrupting the intricate equilibrium of amylose synthesis. The impact of cold temperatures on vital physiological processes, such as the metabolic pathways associated with amylose synthesis, is evident. This phenomenon results in a measurable effect on total amylose's overall quantity and efficiency. The impact of cold stress on early-sown crops is apparent, as it leads to decreased and irregular amylose levels, which can have implications for the quality and functionality of the resulting starch, ultimately affecting the overall productivity of the crop. On the other hand, sowing crops later than usual introduces a distinct array of environmental stress factors that impact the overall amylose content in agricultural produce. The compressed duration of the growing season places considerable stress on plants, compelling them to accelerate both their vegetative and reproductive growth. In the given situation, the condensed duration may reduce the overall amylose content as plants expedite their growth stages to allocate resources towards reproductive endeavours. Tangible constraints imposed by time limitations hinder the ability of crops to maximize their general amylose content. This emphasizes the intricate equilibrium necessary to attain an optimal amylose content amidst diverse environmental stressors linked to departure from recommended sowing timing. The timing of recommended sowing is of utmost importance in the scientific study of total amylose content, as it helps determine the most favorable conditions for the growth and development of crops. The temporal coincidence corresponds to advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which contribute to the efficient synthesis of amylose. The synchronization process facilitates the prompt activation of genetic and hormonal mechanisms, resulting in consistent and optimal levels of total amylose content. The suggested timing establishes the foundation for attaining an optimal starch composition, a crucial factor influencing the crop's overall functionality and usefulness in diverse applications. A strategic approach is employed to investigate the potential influence of growth regulators to address the effects of environmental stress on the overall amylose content. Salicylic acid, well-known for its participation in plant defence mechanisms, has the potential to be utilised for the regulation of amylose synthesis during unfavourable circumstances (Zia-ur-Rehman et al., 2023; Laribi et al., 2023; Azizkhani et al., 2023; Yadav and Singh 2023; Nabizade et al., 2023; Das et al., 2023; Feng et al., 2023; Kongala and Kondreddy 2023). This strategic approach becomes especially pertinent for crops that are sown early, as it provides a method to enhance the resilience of plants against the potential negative impacts of late frosts on the process of amylose synthesis. Activating stress response genes by salicylic acid augments the plant's capacity to endure environmental adversities, facilitating a more consistent and ideal total amylose content. In addition, using sodium nitroprusside, which acts as a donor of nitric oxide, offers an intervention to optimize the overall amylose content. When sodium nitroprusside is used carefully and deliberately, it impacts important physiological processes, specifically the synthesis of starch, which is essential for the production of amylose. This application plays a role in determining the ideal total amylose content, which is particularly advantageous for crops that are sown late and need to promote vegetative and reproductive growth within a limited growing season. The intricate utilization of these growth regulators demonstrates their capacity to regulate the physiological reactions of crops when confronted with environmental stressors linked to deviations from the recommended sowing schedule. The investigation into the impact of environmental stress on the overall amylose content in crops provides a comprehensive comprehension of the complex dynamics involving timing, growth conditions, and vegetative and reproductive growth. Crops that are sown early face the obstacle of late frosts, which hinder the achievement of an optimal total amylose content. On the other hand, crops planted late encounter the challenge of a condensed growing season, which affects the synthesis of amylose. Establishing optimal conditions for achieving an ideal total amylose content is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions for improving the resilience of crops. These interventions can potentially impact the overall amylose content and influence the composition and utility of starch in the harvest. This scientific investigation illuminates the environmental stressors encountered by crops and offers a framework for deliberate interventions to address these challenges and enhance amylose content for resilient crop growth(Zia-ur-Rehman et al., 2023; Annabi and Bettaieb 2023; Azizkhani et al., 2023; Yadav and Singh 2023).

Table 4.2.9.1 Effect of treatments on total amylose (%) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Total Amylose-2022			Total Amylose-2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	1.65	2.41	3.98	1.85	2.54	4.18
S0 -Optimum sowing	3.94	5.58	2.35	4.14	5.68	2.55
SL -Late sowing	3.07	2.25	1.61	3.27	2.35	1.81
(Agrochemicals)						
A0- Control	2.91	2.07	2.13	3.11	2.17	2.33
A1-Sodium nitroprusside (250 µM/L)	2.51	2.71	3.06	2.71	2.85	3.26
A2-Salicylic acid (150mg/L)	3.39	5.05	2.93	3.59	5.15	3.13
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	2.73	3.82	2.46	2.93	3.92	2.66
CV (Sowing)	20.05	19.52	22.97	18.76	18.57	21.36
CV (Sowing date and agrochemical)	11.79	12.17	14.39	11.02	10.71	13.38
CD (Sowing)	0.65	7.49	0.68	0.66	7.45	0.65
CD (Agrochemicals)	0.33	3.79	0.37	0.35	3.89	0.38

Table 4.2.9.2 The interaction effect of treatments on total amylose (%) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Total amylose-2022			Total amylose-2023		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
SEA0	1.02^{h}±0.15	2.11^{d}±0.40	3.18^{b}±1.03	1.22^{h} ±0.15	1.85^{c} ±0.72	3.38^{b} ±1.03
SEA1	2.39^{ef}±1.04	2.37^{d}±0.41	4.17^{a}±0.20	2.59^{ef}±1.04	2.36^{b} ±0.24	4.37^{a}±0.20
SEA2	1.67^{g}±0.52	3.15^{c}±0.14	4.14^{a}±0.46	1.87^{g} ±0.52	3.16^{a} ±0.24	4.34^{a} ±0.46
SEA3	1.56^{gh}±0.54	2.77^{d}±0.57	4.44^{a}±0.32	1.76^{gh} ±0.54	2.79^{b} ±0.46	4.64^{a} ±0.32
S0A0	4.62^{ab}±0.46	2.78^{d}±0.59	2.04^{de}±0.33	4.82^{ab} ±0.46	2.88^{b} ±0.59	2.24^{de} ±0.33
S0A1	2.98^{def}±0.37	10.48^{a}±13.27	2.85^{bc}±0.33	3.18^{def} ±0.37	3.08^{a} ±0.37	3.05^{bc} ±0.33
S0A2	4.68^{a}±0.29	7.07^{b}±8.55	3.09^{b}±0.25	4.88^{a} ±0.29	3.46^{a} ±2.13	3.29^{b}±0.25
S0A3	3.49^{cd}±0.36	1.78^{e}±0.73	1.42^{de}±0.34	3.69^{cd} ±0.36	1.33^{c} ±0.30	1.62^{de} ±0.34
SLA0	3.12^{de}±0.20	1.93^{e}±1.20	1.19^{e}±0.14	3.32^{de} ±0.20	1.80^{c} ±0.80	1.39^{e} ±0.14
SLA1	2.18^{fg}±0.43	2.69^{d}±0.41	2.18^{cd}±0.43	2.38^{fg} ±0.43	3.11^{a} ±0.38	2.38^{cd} ±0.43
SLA2	3.84^{bc}±0.34	2.15^{d}±0.44	1.56^{de}±0.20	4.04^{bc} ±0.34	2.17^{b} ±0.34	1.76^{de} ±0.20
SLA3	3.15^{de}±0.16	1.55^{e}±0.93	1.53^{de}±0.45	3.35^{de} ±0.16	2.33^{b} ±0.41	1.73^{de} ±0.45
CV	11.79	12.17	14.39	11.02	10.71	13.38
CD	0.82	9.32	0.88	0.81	9.29	0.86

Figure 4.2.9.1a. Effect of sowing dates and agrochemicals treatments on total amylose (%) of maize at 30, 60, and 90 DAS during spring season 2022

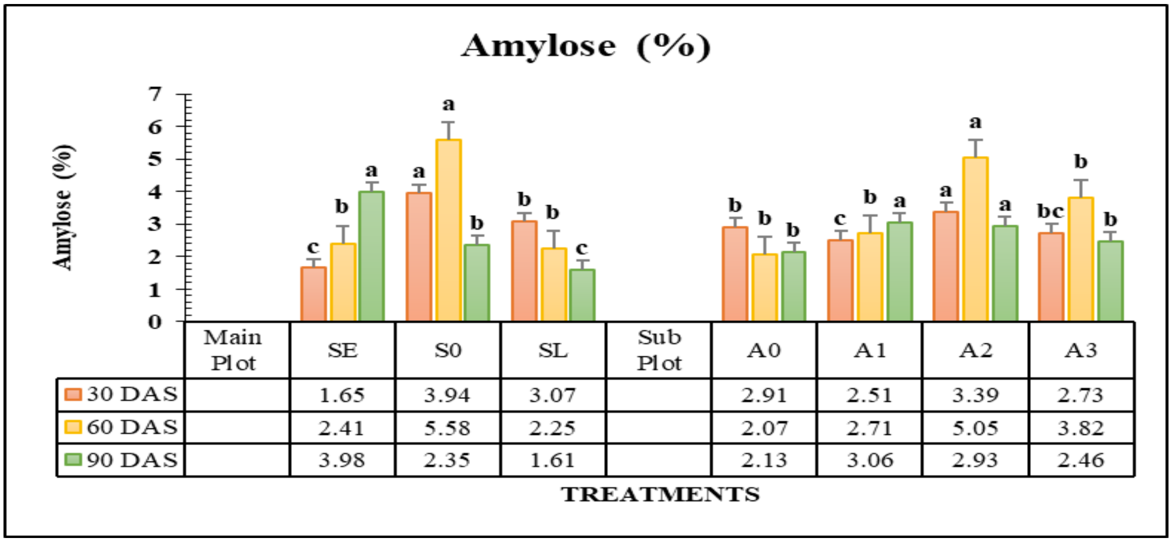
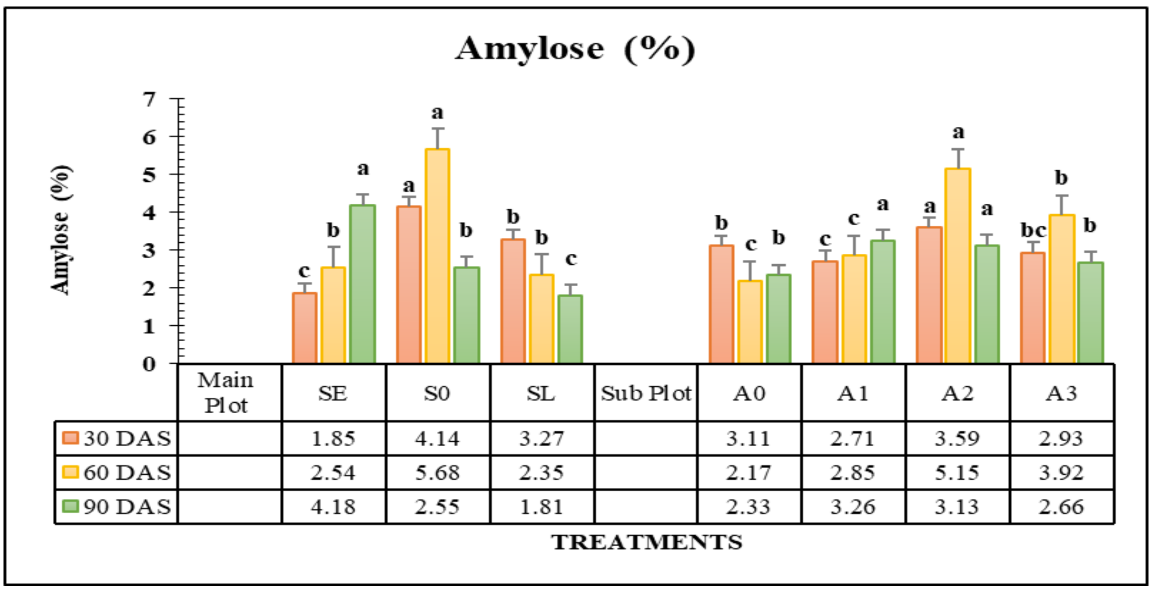


Figure 4.2.9.2b. Effect of sowing dates and agrochemicals treatments on total amylose (%) of maize at 30, 60, and 90 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.10 Total Reducing Sugar (microgram/ml): The impact of different sowing dates and agrochemicals on the Total Reducing Sugar (microgram/ml) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30DAS, 60DAS, and 90 DAS (Table 4.2.10.1, 4.2.10.2 and Figure 4.2.10.1a, 4.2.10.2b). In 2022 and 2023, there was a significant difference in the percentage of Total Reducing Sugar (microgram/ml) sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals; it was estimated by comparing all the standards with control. Thus, the percentage pattern in Total Reducing Sugar (microgram/ml) was observed at 30, 60, and 90 DAS. In the year 2022, it was found that early sowing (SE) decreased the percentage by 94.28%, and late sowing (SL) decreased the rate by 9.41% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing (SE) reduced the percentage by 10.80%, and late sowing decreased the rate by 12.22%, respectively. In the case of 90 DAS, the early sowing (SE) reduced the percentage by 8.63% and late sowing (SL) reduced the percentage by 12.31% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 increased the rate by 37.42%, A2 increased by 66.07%, and A3 increased the percentage by 26.92% as compared to control (A0) at 30 DAS. At 60 DAS, the A1, A2, and A3 raised the rate by 84.91%, 37.09%, and 0.94%, respectively as compared to the control. In the case of 90 DAS, the percentage increased in A1, A2, and A3 decreased by 85.52%, 32.80%, and 1.30%, respectively, compared to the control (A0). In the year 2023, the early sowing (SE) decreased the percentage by 92.82% and late sowing (SL) increased the rate by 9.27% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, early sowing (SE) decreased the percentage by 10.61%, and late sowing decreased by 12.00%, respectively. In the case of 90 DAS, the early sowing (SE) decreased the percentage by 8.57% and late sowing (SL) reduced the rate by 12.22% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 increased the percentage by 36.30%, A2 increased by 88.09%, and A3 increased the rate by 49.85% compared to control (A0) at 30 DAS. At 60 DAS, the A1, A2, and A3 increased the percentage by 82.71%, 66.81%, and 1.55%, respectively when compared to the control. In the case of 90 DAS, the rate increased in A1 and A2 and decreased in A3 by 84.66%, 60.25%, and 2.08%, respectively, compared to the control (A0). Within the complex realm of crop physiology, the comprehensive quantification of reducing sugar content is a significant indicator, offering valuable insights into the plant's adaptive response to various environmental stressors. This study investigates the intricate dynamics of total reducing sugars in crops exposed to untimely sowing, either prematurely or delayed, in contrast to the prescribed planting timetable. Comprehending the fluctuations in overall levels of reducing sugars is crucial to elucidate the influence of environmental factors, timing of germination, and subsequent growth and reproductive processes. Sowing seeds at an early stage subjects the developing seedlings to various environmental stressors, notably affecting reduced sugars' overall content. Late spring frosts present a significant hazard, potentially disrupting the intricate equilibrium of sugar synthesis. The impact of cold temperatures on vital physiological processes, such as the metabolic pathways responsible for sugar synthesis, is evident. This phenomenon results in a measurable effect on total reducing sugars' overall quantity and efficiency. The impact of cold stress is apparent in crops that are planted early, as it can lead to a decrease in sugar content and cause uneven distribution. This could disrupt the crop's metabolic processes and overall energy equilibrium. On the other hand, sowing crops later than usual introduces a distinct array of environmental stress factors that impact the overall levels of reducing sugars. The compressed duration of the growing season places considerable stress on plants, compelling them to accelerate both their vegetative and reproductive growth. In the given situation, the shortened course may lead to a potential decrease in the overall concentration of reducing sugars. This is because plants may expedite their growth stages to allocate resources towards reproductive processes. Tangible time constraints hinder the ability of crops to maximize their overall reduced sugar content. This underscores the intricate equilibrium necessary to attain an optimal reduction in sugar content in light of diverse environmental stressors linked to deviation from recommended sowing timing. The timing of sowing, as instructed, holds significant importance in scientific research about the measurement of total reducing sugar content. This recommendation aids in determining the most favourable conditions for the growth and development of crops. The temporal occurrence coincides with advantageous ecological circumstances, encompassing factors such as temperature, soil moisture, and duration of daylight, all of which collectively facilitate the efficient process of sugar synthesis. The synchronization enables the prompt initiation of genetic and hormonal mechanisms, resulting in a consistent and ideal overall reduction in sugar levels. The suggested timing establishes the foundation for optimal metabolic equilibrium, a crucial factor in crop development and efficiency. A strategic approach is employed to investigate the potential influence of growth regulators to address the adverse effects of environmental stress on the general reducing sugar content. Salicylic acid, well-known for its participation in plant defence mechanisms, has the potential to be utilized for the regulation of sugar synthesis in unfavorable environmental circumstances (Muhammad et al., 2024; Umair et al., 2024; Nyfeler et al., 2024; Basit et al., 2024; Yonglu Wang et al., 2024). The utilization of this strategic approach holds significant importance in the context of crops that are sown early, as it provides a method to enhance the resilience of plants against the potential adverse impacts of late frosts, which can impede the process of sugar synthesis. Salicylic acid's activation of stress response genes has been found to enhance the plant's capacity to endure environmental challenges, thereby facilitating a more consistent and optimal total reducing sugar content. Moreover, the utilization of sodium nitroprusside, which acts as a donor of nitric oxide, offers an intervention to optimize the overall concentration of reducing sugars. When sodium nitroprusside is applied prudently, it exerts an influence on vital physiological processes, specifically the synthesis of sugar, which is essential for reducing sugar production. This application aids in achieving the ideal total reducing sugar content, which is particularly advantageous for crops that are sown late and need to enhance both vegetative and reproductive growth despite a shortened growing season. The precise application of these growth regulators demonstrates their capacity to regulate the physiological reactions of crops when confronted with environmental stressors that arise from deviations in recommended sowing schedules. The investigation into the impact of environmental stress on the overall levels of reducing sugars in crops provides a comprehensive comprehension of the complex interactions between timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops that are sown early face the obstacle of late frosts, which hinder the production of optimal total reducing sugar content. On the other hand, crops planted late encounter the stress of a condensed growing season, which affects the synthesis of sugar (Begum et al., 2024; Umair et al., 2024; Nyfeler et al., 2024; Agus et al., 2024; Aydın 2024; Namatsheve et al., 2024; Basit et al., 2024; Wang et al., 2024). The determination of the appropriate timing for sowing, based on scientific principles, is crucial in creating favourable conditions to achieve an optimal level of total reducing sugar content. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions for improving the resilience of crops. These interventions can impact the overall metabolic balance and productivity of the yield and influence the content of total reducing sugars. This scientific investigation illuminates the environmental stressors encountered by crops. It presents a framework for deliberate interventions to address these challenges and optimise the reduction of sugar content for resilient crop growth.

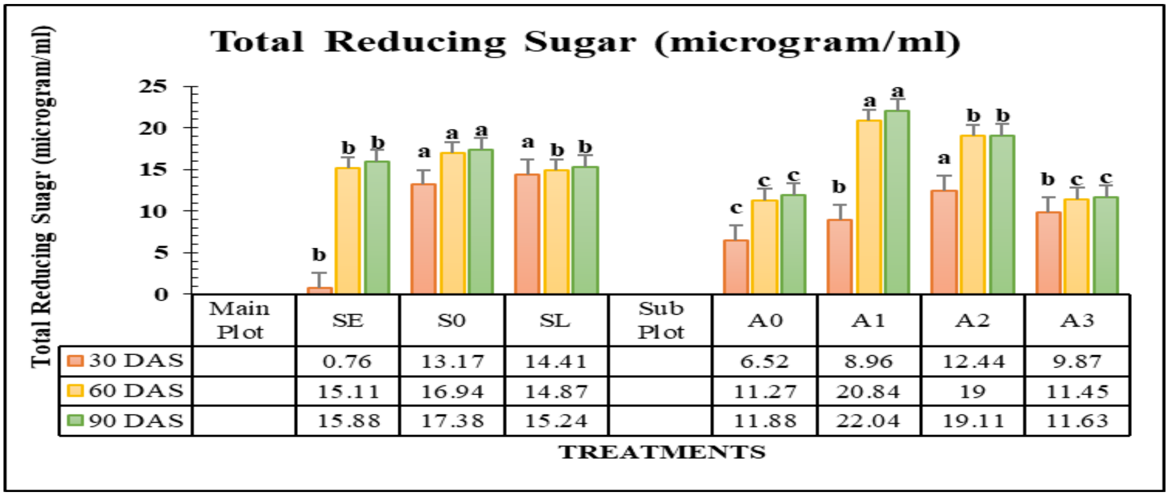
Table 4.2.10.1 Effect of treatments on total reducing sugar of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Total reducing sugar-2022			Total reducing sugar-2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	0.76	15.11	15.88	0.96	15.41	16.00
S0 -Optimum sowing	13.17	16.94	17.38	13.37	17.24	17.50
SL -Late sowing	14.41	14.87	15.24	14.61	15.17	15.36
(Agrochemicals)						
A0- Control	6.52	11.27	11.88	6.72	11.57	12.00
A1-Sodium nitroprusside (250 µM/L)	8.96	20.84	22.04	9.16	21.14	22.16
A2-Salicylic acid (150mg/L)	12.44	19.00	19.11	12.64	19.30	19.23
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	9.87	11.45	11.63	10.07	11.75	11.75
CV (Sowing)	20.49	3.28	5.55	20.07	3.22	5.51
CV (Sowing date and agrochemical)	14.07	6.30	7.74	13.78	6.18	7.69
CD (Sowing)	2.19	0.58	1.01	2.17	0.59	1.02
CD (Agrochemicals)	1.31	0.97	1.24	1.35	0.95	1.25

Table 4.2.10.2 The interaction effect of treatments on total reducing sugar of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022 and 2023

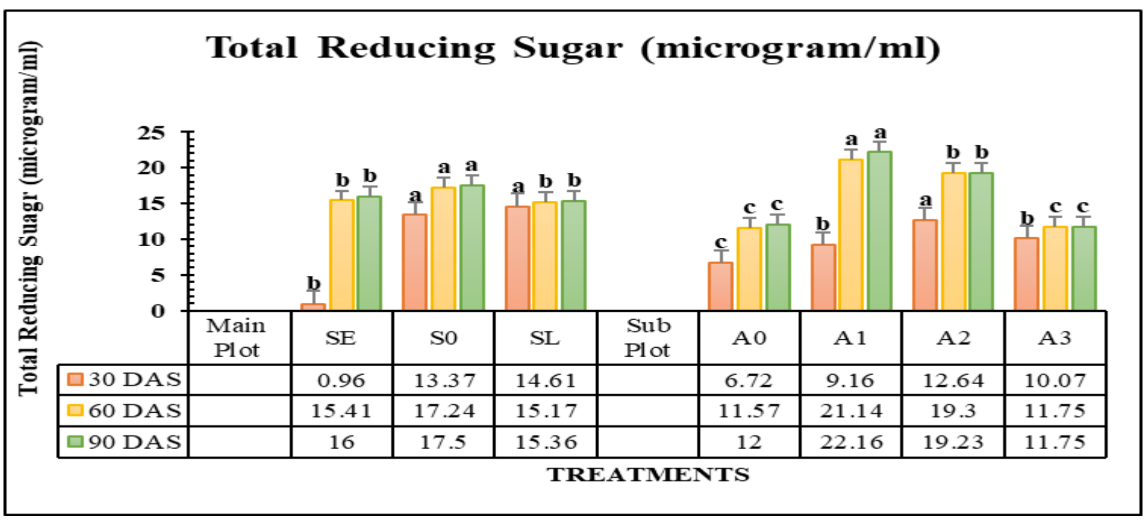
Treatments	Total reducing sugar-2022			Total reducing sugar-2023		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
SEA0	0.17^{g}±0.11	9.96^{e}±0.36	10.55^{f}±0.34	0.41^{g}±0.12	10.29^{e}±0.37	10.64^{f}±0.36
SEA1	0.98^{g}±1.14	21.91^{a}±2.15	25.67^{a}±0.36	1.15^{g}±1.17	22.25^{a}±2.17	25.76^{a}±0.41
SEA2	1.11^{g}±1.03	21.29^{a}±0.38	20.25^{c}±4.29	1.34^{g}±1.01	21.63^{a}±0.34	20.33^{c}±4.26
SEA3	0.79^{g}±0.47	7.29^{f}±0.38	7.05^{g}±0.32	1.03^{g}±0.48	7.63^{f}±0.40	7.14^{g}±0.32
S0A0	7.77^{f}±1.20	16.63^{cd}±0.58	17.32^{de}±0.83	8.00^{f}±1.17	16.96^{cd}±0.59	17.40^{de}±0.82
S0A1	11.77^{de}±4.43	22.05^{a}±0.79	23.03^{b}±0.62	12.01^{de}±4.40	22.39^{a}±0.81	23.12^{b}±0.61
S0A2	15.53^{bc}±0.29	17.91^{bc}±1.76	17.94^{de}±0.45	15.76^{bc}±0.34	18.25^{bc}±1.75	18.02^{de}±0.43
S0A3	17.63^{b}±0.22	11.20^{e}±0.43	11.27^{f}±0.72	17.86^{b}±0.18	11.53^{e}±0.43	11.36^{f}±0.78
SLA0	11.63^{e}±1.43	7.25^{f}±0.36	7.79^{g}±0.33	11.86^{e}±1.38	7.58^{f}±0.31	7.88^{g}±0.29
SLA1	14.15^{cd}±0.38	18.58^{b}±0.91	17.44^{de}±0.94	14.38^{cd}±0.34	18.91^{b}±0.96	17.52^{de}±0.93
SLA2	20.70^{a}±0.94	17.82^{bc}±0.92	19.17^{cd}±0.36	20.93^{a}±0.93	18.15^{bc}±0.90	19.26^{cd}±0.36
SLA3	11.20^{e}±0.22	15.86^{d}±0.52	16.58^{e}±0.65	11.43^{e}±0.18	16.20^{d}±0.53	16.67^{e}±0.67
CV	14.07	6.30	7.74	13.78	6.18	7.69
CD	2.92	1.56	2.10	2.28	1.58	2.10

Figure 4.2.10.1a. n Effect of sowing dates and agrochemicals treatments on total reducing sugar of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		0.76	13.17	14.41		6.52	8.96	12.44	9.87
60 DAS		15.11	16.94	14.87		11.27	20.84	19	11.45
90 DAS		15.88	17.38	15.24		11.88	22.04	19.11	11.63

Figure 4.2.10.2b. Effect of sowing dates and agrochemicals treatments on total reducing sugar of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		0.96	13.37	14.61		6.72	9.16	12.64	10.07
60 DAS		15.41	17.24	15.17		11.57	21.14	19.3	11.75
90 DAS		16	17.5	15.36		12	22.16	19.23	11.75

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.11 Total Non-Reducing Sugar (microgram/ml): The impact of different sowing dates and agrochemicals on total Non-Reducing Sugar (microgram/ml) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90. DAS is shown in (Table 4.2.11.1 4.2.11.2 and Figure 4.2.11.1a, 4.2.11.2b). In 2022 and 2023, there was a significant difference in the percentage of Total Non-Reducing Sugar (microgram/ml) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals it was calculated by comparing all the mean with control. Thus, the percentage pattern in Total Non-Reducing Sugar (microgram/ml) was observed at 30, 60, and 90 DAS. In the year 2022, it was found that early sowing (SE) decreased the percentage by 80.04%, and late sowing (SL) increased the percentage by 7.17% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing (SE) increased the percentage by 13.46%, and the late sowing decreased by 5.79%, respectively. In the case of 90 DAS, the early sowing (SE) reduced the rate by 37.49% and late sowing (SL) decreased the percentage by 13.53% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 increased the percentage by 8.39%, A2 decreased by 11.19%, and A3 decreased the percentage by 10.25% as compared to control (A0) at 30 DAS. At 60 DAS, the A1 decreased, whereas A2 and A3 increased the percentage by 10.06%, 30.11%, and 28.67%, respectively, compared to the control. In the case of 90 DAS, the percentage decreased in A1, A2, and A3 by 12.53%, 57.92%, and 40.89%, respectively, compared to the control (A0). In the year 2023, the early sowing (SE) decreased the percentage by 80.244%, and the late sowing (SL) increased the percentage by 7.18% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, early sowing (SE) increased the percentage by 13.53%, and late sowing decreased by 19.89%, respectively. In the case of 90 DAS, the early sowing (SE) decreased the percentage by 37.37%, and the late sowing (SL) decreased the percentage by 13.49% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 increased the percentage by 8.41%, A2 decreased by 12.17%, and A3 decreased the percentage by 9.04% as compared to control (A0) at 30 DAS. At 60 DAS, the A1 decreased, and A2 and A3 increased the percentage by 10.10%, 27.19%, and 21.74%, respectively, compared to the control. In the case of 90 DAS, A1 decreased, and A2 and A3 increased by 12.47%, 50.42%, and 61.31%, respectively, compared to the control (A0). Within the complex realm of crop physiology, the comprehensive assessment of total non-reducing sugar content assumes a pivotal role, providing significant insights into the adaptive mechanisms of plants in response to various environmental stressors. This study investigates the intricate interactions of total non-reducing sugars in crops exposed to untimely sowing, either early or too late, instead of adhering to the recommended planting timetable. Comprehending the fluctuations in the overall concentration of non-reducing sugars is imperative to elucidate the effects of environmental factors, timing of germination, and subsequent growth and reproductive processes (Begum et al., 2024; Umair et al., 2024; Nyfeler et al., 2024; Agus et al., 2024; Honglu Wang et al., 2024; He et al., 2024; Yonglu Wang et al., 2024). The practice of sowing seeds at an early stage exposes the nascent seedlings to various environmental stressors, notably affecting the overall content of non-reducing sugars. Late spring frosts present a significant hazard, potentially disrupting the intricate equilibrium of sugar synthesis. The impact of cold temperatures on essential physiological processes, such as the metabolic pathways responsible for synthesising non-reducing sugars, is evident. This phenomenon has a measurable effect on total non-reducing sugars' overall quantity and efficiency. The impact of cold stress on early-sown crops becomes apparent through diminished and irregular levels of non-reducing sugars, potentially undermining the crop's metabolic functions and overall energy equilibrium. On the other hand, sowing crops later than usual presents distinct environmental stress factors that impact the overall concentration of non-reducing sugars in the crops. The compressed duration of the growing season places considerable stress on plants, compelling them to accelerate both their vegetative and reproductive growth. In this situation, the shortened course may lead to a potential decrease in non-reducing sugars. This is because plants may expedite their growth stages to allocate resources towards reproductive processes. Tangible time constraints hinder the ability of crops to maximize their overall non-reducing sugar content. This underscores the intricate equilibrium necessary to attain an optimal non-reducing sugar concentration in light of diverse environmental stressors linked to departure from the recommended sowing schedule. The timing of sowing, as instructed, is of utmost importance in the scientific study of total non-reducing sugar content, as it determines the ideal conditions for crop growth and development. The synchronization corresponds to advantageous environmental circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which contribute to the practical synthesis of non-reducing sugars. The synchronization facilitates the prompt initiation of genetic and hormonal mechanisms, resulting in consistent and optimal levels of total non-reducing sugars. The suggested timing establishes the foundation for optimal metabolic equilibrium, a crucial crop development and efficiency factor. To address the effects of environmental stress on the overall concentration of non-reducing sugars, a systematic approach is employed to investigate the potential influence of growth regulators. Salicylic acid, well-known for its role in plant defence mechanisms, has the potential to be utilized for regulating sugar production in unfavourable circumstances (Begum et al., 2024; Umair et al., 2024; Nyfeler et al., 2024; Agus et al., 2024; Wang et al., 2024; He et al., 2024; Silva et al., 2024; Wei et al., 2024; Wang et al., 2024; Li et al., 2024; Aggarwal et al., 2024; Wang et al., 2024). This strategic approach becomes especially pertinent for crops that are planted early, as it provides a method to enhance the resilience of plants against the potential adverse impacts of late frosts on the synthesis of non-reducing sugars. Salicylic acid's activation of stress response genes has been observed to enhance the plant's capacity to endure environmental challenges, facilitating a more consistent and optimal total non-reducing sugar content. In addition, using sodium nitroprusside, which acts as a donor of nitric oxide, presents an intervention to optimise the overall concentration of non-reducing sugars. When administered carefully, sodium nitroprusside impacts vital physiological mechanisms, specifically the synthesis of sugars essential for producing non-reducing sugars. This application aids in determining the ideal amount of total non-reducing sugars, which is particularly advantageous for crops planted late and needs to promote both vegetative and reproductive growth despite a shorter growing season. The intricate utilization of these growth regulators demonstrates their capacity to regulate the physiological reactions of crops when confronted with environmental stressors that arise from deviations in recommended sowing timing. The investigation into the impact of environmental stress on the overall concentration of non-reducing sugars in crops provides a comprehensive comprehension of the complex dynamics involving timing, growth conditions, and vegetative and reproductive growth. Crops planted early face the obstacle of late frosts, which hinder the attainment of an ideal total non-reducing sugar content. On the other hand, crops that are planted late encounter the challenge of a condensed growing season, which affects the process of sugar synthesis. Establishing optimal conditions for achieving an ideal total non-reducing sugar content is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies provides strategic interventions to improve crops' resilience. These interventions can impact the yield's overall metabolic balance and productivity and influence the levels of total non-reducing sugars present. This scientific investigation illuminates the environmental pressures encountered by crops. It presents a framework for deliberate interventions to address these challenges and enhance the non-reducing sugar content for resilient crop growth (Begum, et al., 2024; Umair et al., 2024; Nyfeler et al., 2024; Agus et al., 2024; Wang et al., 2024; He et al., 2024; Silva et al., 2024; Boukaew et al., 2024; Wang et al., 2024; Li et al., 2024; Aggarwal et al., 2024; Srivastava and Gupta 2024; Aydın 2024; Namatsheve et al., 2024).

Table 4.2.11.1 Effect of treatments on total non-reducing sugar of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Total non-reducing sugar 2022			Total non-reducing sugar 2023		
At different Interval	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
(Sowing Date)						
SE -Early sowing	8.18	46.58	15.47	8.08	46.48	15.55
S0 -Optimum sowing	41.00	19.85	24.75	40.90	19.75	24.83
SL -Late sowing	43.94	18.70	21.40	43.84	15.82	21.48
(Agrochemicals)						
A0- Control	32.06	25.03	16.44	31.96	24.93	16.52
A1-Sodium nitroprusside (250 µM/L)	34.75	22.51	14.38	34.65	22.41	14.46
A2-Salicylic acid (150mg/L)	28.17	31.81	24.77	28.07	31.71	24.85
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	29.17	34.15	26.57	29.07	30.35	26.65
CV (Sowing)	3.53	8.97	8.64	3.54	6.20	8.60
CV (Sowing date and agrochemical)	11.35	57.07	27.32	11.39	22.22	27.21
CD (Sowing)	1.24	2.88	2.01	1.26	1.92	2.11
CD (Agrochemicals)	3.48	7.48	5.55	3.52	6.02	5.25

Table 4.2.11.2 Interaction effect of treatments on total non-reducing sugar of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Total non-reducing sugar-2022			Total non-reducing sugar-2023		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
SEA0	6.98^{f}±0.70	39.09^{b}±9.06	9.72^{i}±0.70	7.17^{f}±0.84	39.23^{b}±7.12	9.85^{h}±0.78
SEA1	13.59^{e}±8.11	35.54^{bc}±2.61	1.98^{j}±0.14	13.77^{e}±7.11	35.69^{bc}±2.14	2.10^{i}±0.16
SEA2	5.67^{f}±1.63	45.72^{b}±1.39	15.95^{h}±3.68	5.86^{f}±1.65	45.87^{b}±1.25	16.08^{g}±2.65
SEA3	6.50^{f}±1.44	59.31^{a}±1.29	34.24^{a}±0.18	6.69^{f}±1.55	59.46^{a}±1.98	34.37^{a}±0.15
S0A0	46.17^{a}±2.77	7.94^{g}±8.00	15.45^{h}±8.41	46.36^{a}±2.14	8.08^{fg}±5.25	15.58^{gh}±7.45
S0A1	45.36^{ab}±4.75	15.00^{efg}±5.13	21.65^{f}±6.83	45.55^{ab}±4.65	15.15^{ef}±5.16	21.78^{ef}±5.46
S0A2	38.82^{cd}±1.89	26.24^{cde}±5.16	31.74^{b}±2.05	39.00^{cd}±2.10	26.38^{d}±10.35	31.87^{b}±5.52
S0A3	33.66^{d}±0.73	30.23^{cd}±3.67	30.16^{c}±9.06	33.85^{d}±1.65	30.38^{cd}±3.54	30.28^{c}±6.45
SLA0	43.02^{abc}±4.62	21.41^{def}±3.83	24.16^{e}±0.58	43.21^{abc}±0.45	21.56^{de}±5.45	24.29^{e}±2.65
SLA1	45.32^{ab}±1.19	17.00^{efg}±5.34	19.51^{g}±9.72	45.51^{ab}±0.16	17.15^{ef}±1.65	19.64^{f}±1.58
SLA2	40.05^{bc}±1.30	23.49^{def}±1.05	26.61^{d}±0.47	40.23^{bc}±1.30	23.64^{de}±1.28	26.74^{d}±0.38
SLA3	47.37^{a}±0.37	19.93^{fg}±9.16	15.31^{h}±1.29	47.56^{a}±0.35	19.74^{g}±0.35	15.44^{gh}±0.85
CV	11.35	57.07	27.32	11.39	22.22	27.21
CD	5.37	11.56	8.56	5.40	9.22	8.35

Figure 4.2.11.1a. Effect of sowing dates and agrochemicals treatments on total non-reducing sugar of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022

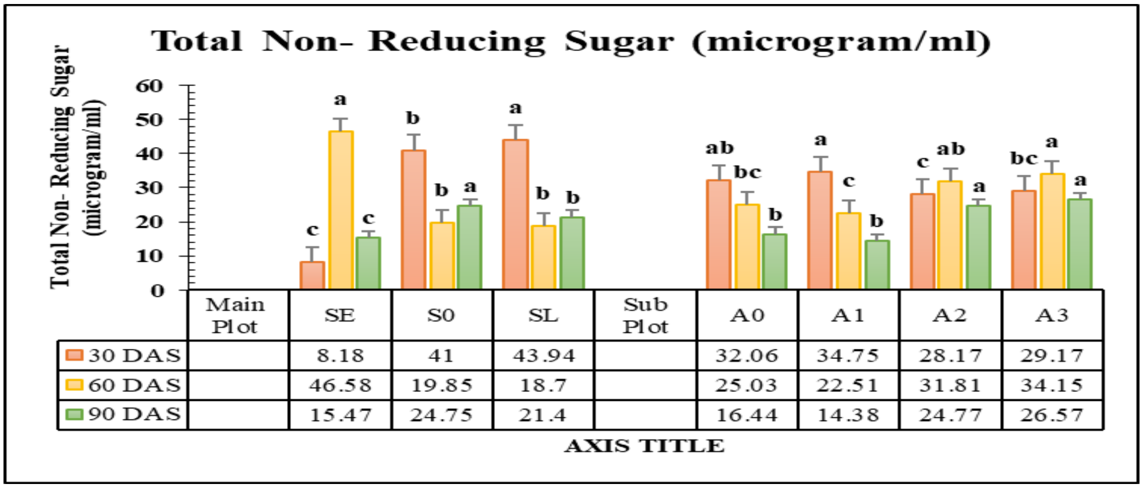
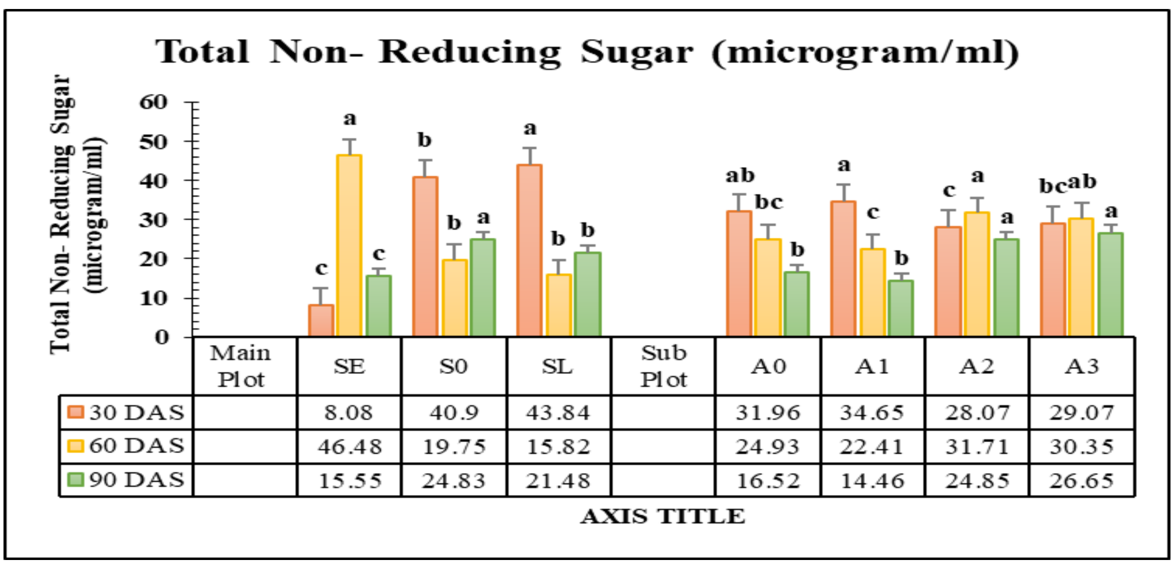


Figure 4.2.11.2b. Effect of sowing dates and agrochemicals treatments on total non-reducing sugar of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.12 Lipid Peroxidation (micromoles MDA per gram fresh weight): The impact of different sowing dates and agrochemicals on Lipid Peroxidation (micromoles MDA per gram fresh weight) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30DAS, 60DAS, and 90 DAS (Table 4.2.12.1, 4.2.12.2 and Figure 4.2.12.1a, 4.2.12.2b). In 2022 and 2023, there was a significant difference in the percentage of Lipid Peroxidation (micromoles MDA per gram fresh weight) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals; it was estimated by comparing all the standards with control. Thus, the percentage pattern in Lipid Peroxidation (micromoles MDA per gram fresh weight) was observed at 30, 60, and 90 DAS. In the year 2022, it was found that early sowing (SE) increased the percentage by 43.98%, and late sowing (SL) decreased the rate by 57.33% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing (SE) reduced the percentage by 24.71%, and the late sowing decreased by 6.86%, respectively. In the case of 90 DAS, the early sowing (SE) increased the percentage by 73.49% and late sowing (SL) decreased the percentage by 6.30% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 reduced the rate by 22.65%, A2 decreased by 37.98%, and A3 decreased the percentage by 54.88% as compared to control (A0) at 30 DAS. At 60 DAS, the rate decreased in A1, A2, and A3 by 46.63%, 86.25%, and 67.49% respectively compared to the control. In the case of 90 DAS, the percentage decreased in A1, A2, and A3 by 35.65%, 78.01%, and 62.91%, respectively, compared to the control (A0). In the year 2023, the early sowing (SE) increased the percentage by 37.13%, and the late sowing (SL) decreased the rate by 48.16% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, early sowing (SE) reduced the percentage by 50.82%, and late sowing decreased by 6.36%, respectively. In the case of 90 DAS, the early sowing (SE) increased the percentage by 68.68%, and the late sowing (SL) increased the rate by 8.19% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 decreased the percentage by 19.75%, A2 decreased by 25.57%, and A3 reduced the rate by 33.69% compared to control (A0) at 30 DAS. At 60 DAS, the percentage decreased in A1, A2, and A3 by 18.35%, 19.25%, and 6.41% respectively compared to the control. In the case of 90 DAS, the percentage decreased in A1, A2, and A3 by 35.37%, 49.08%, and 31.27%, respectively, compared to the control

(A0). Within the complex domain of crop physiology, lipid peroxidation is a critical parameter, offering valuable insights into the mechanisms by which plants react to various environmental stressors. This study examines the intricate mechanisms of lipid peroxidation in crops exposed to untimely sowing, either in advance or delayed, in contrast to the suggested planting timetable. Comprehending the diverse manifestations of lipid peroxidation is crucial in elucidating the ramifications of environmental factors, timing of germination, and subsequent growth and reproductive processes. Sowing seeds at an early stage subjects the developing seedlings to various environmental stressors, which notably affect lipid peroxidation. Late spring frosts present a significant risk, which has the potential to disturb the intricate equilibrium of cellular membranes and initiate processes of lipid peroxidation. Exposure to cold temperatures has been found to disrupt essential physiological processes, such as membrane integrity and lipid composition. This phenomenon results in a measurable influence on lipid peroxidation's total amount and effectiveness. The impact of cold stress is observable in crops planted early, as it can result in increased lipid peroxidation, which can potentially undermine the integrity of cellular structure. This, in turn, can lead to diminished membrane integrity and hindered growth of the plants. On the other hand, delayed sowing presents distinct environmental stress factors that impact the process of lipid peroxidation in crops (Wang et al., 2024; Zhang et al., 2024; Wang et al., 2024; Loaiza et al., 2024; Gaurav et al., 2024). The compressed duration of the growing season places considerable stress on plants, compelling them to accelerate both their vegetative and reproductive growth. In this situation, the condensed time frame could potentially lead to a trade-off in lipid peroxidation as plants expedite their growth stages to allocate resources towards reproductive processes. The tangible constraints imposed by time limitations hinder crops' ability to effectively regulate lipid peroxidation. This underscores the intricate equilibrium necessary to attain an optimal lipid peroxidation profile in the presence of diverse environmental stressors linked to departure from recommended sowing timing. The timing of recommended sowing plays a crucial role in the scientific study of lipid peroxidation, as it establishes the most favourable conditions for the growth and development of crops. The synchronisation corresponds to advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which contribute to the optimal stability of membranes and composition of lipids. The synchronisation process facilitates the timely initiation of genetic and hormonal mechanisms, resulting in consistent and optimal lipid peroxidation levels. The suggested timing establishes the foundation for attaining an optimal membrane structure, a critical factor influencing the crop's overall development and yield. To address the consequences of environmental stress on lipid peroxidation, a strategic methodology is employed to investigate the involvement of growth regulators. Salicylic acid, well-known for its participation in plant defence mechanisms, can be utilised to regulate lipid peroxidation during unfavourable circumstances. This strategic approach is especially significant for crops that are planted early, as it provides a method to enhance the resilience of plants against potential negative impacts caused by late frosts on the stability of their membranes and the composition of lipids. Salicylic acid's activation of stress response genes has been found to enhance the plant's capacity to endure environmental challenges, potentially leading to a more consistent and optimal lipid peroxidation profile. When sodium nitroprusside is used carefully and deliberately, it impacts important physiological processes such as the stability of cell membranes and the composition of lipids. These processes are fundamental to the occurrence of lipid peroxidation. This application promotes the attainment of ideal lipid peroxidation levels, which is particularly advantageous for crops that are planted late and need to enhance both vegetative and reproductive growth despite a shortened growing season. The intricate utilisation of these growth regulators showcases their capacity to regulate the physiological reactions of crops when confronted with environmental stressors linked to deviations from the recommended sowing schedule. The investigation into the impact of environmental stress on lipid peroxidation in crops provides a holistic comprehension of the complex dynamics involving timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops that are sown early face the obstacle of late frosts, which hinder the process of lipid peroxidation, leading to suboptimal outcomes. On the other hand, crops that are sown late encounter the stress of a shortened growing season, which affects the stability of their membranes and the composition of their lipids. Establishing an ideal lipid peroxidation profile is contingent upon adhering to scientifically based principles when determining the recommended timing for sowing. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions for improving the resilience of crops. These interventions have the potential to impact lipid peroxidation levels, as well as influence the overall stability of crop membranes and productivity. The present scientific investigation illuminates the various environmental stressors encountered by crops. It offers a potential course of action for deliberate interventions to effectively manage these challenges and enhance lipid peroxidation to promote resilient crop growth(Baranski et al., 2024; Xu et al., 2024; Jing and Huang 2024; Song et al., 2024; Basit et al., 2024).

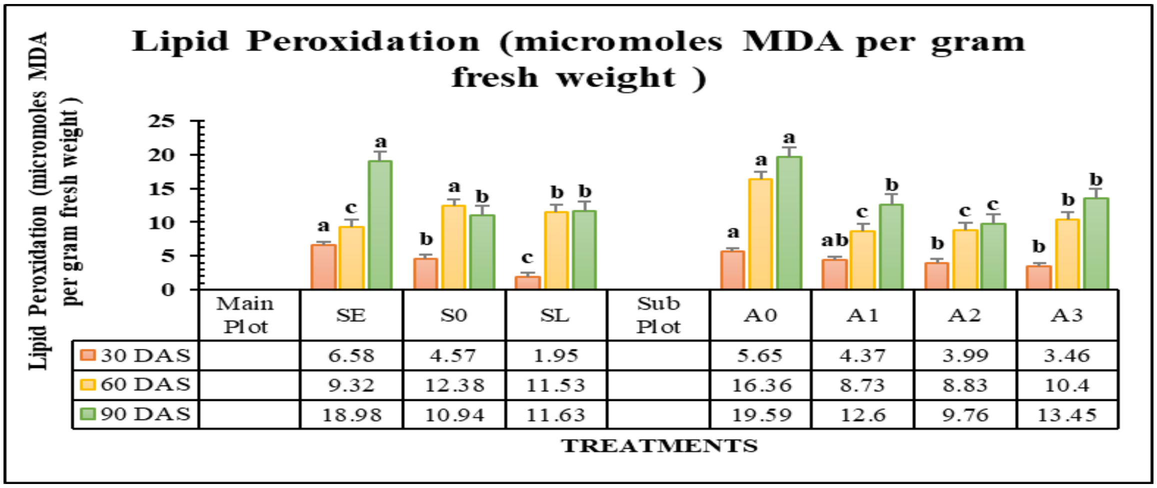
Table 4.2.12.1 Effect of treatments on lipid peroxidation (micromoles MDA per gram fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Lipid peroxidation-2022			Lipid peroxidation-2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	6.58	9.32	18.98	7.46	6.57	19.77
S0 -Optimum sowing	4.57	12.38	10.94	5.44	13.36	11.72
SL -Late sowing	1.95	11.53	11.63	2.82	12.51	12.68
(Agrochemicals)						
A0- Control	5.65	16.36	19.59	6.53	12.15	20.72
A1-Sodium nitroprusside (250 µM/L)	4.37	8.73	12.60	5.24	9.92	13.39
A2-Salicylic acid (150mg/L)	3.99	8.83	9.76	4.86	9.81	10.55
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	3.46	10.40	13.45	4.33	11.37	14.24
CV (Sowing)	39.80	81.52	8.65	33.18	16.41	8.72
CV (Sowing date and agrochemical)	31.30	77.02	13.09	26.09	14.20	11.13
CD (Sowing)	1.97	10.24	1.35	1.89	2.01	1.45
CD (Agrochemicals)	1.35	8.45	1.79	1.33	1.52	1.62

Table 4.2.12.2 The interaction effect of treatments on lipid peroxidation (micromoles MDA per gram fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022 and 2023

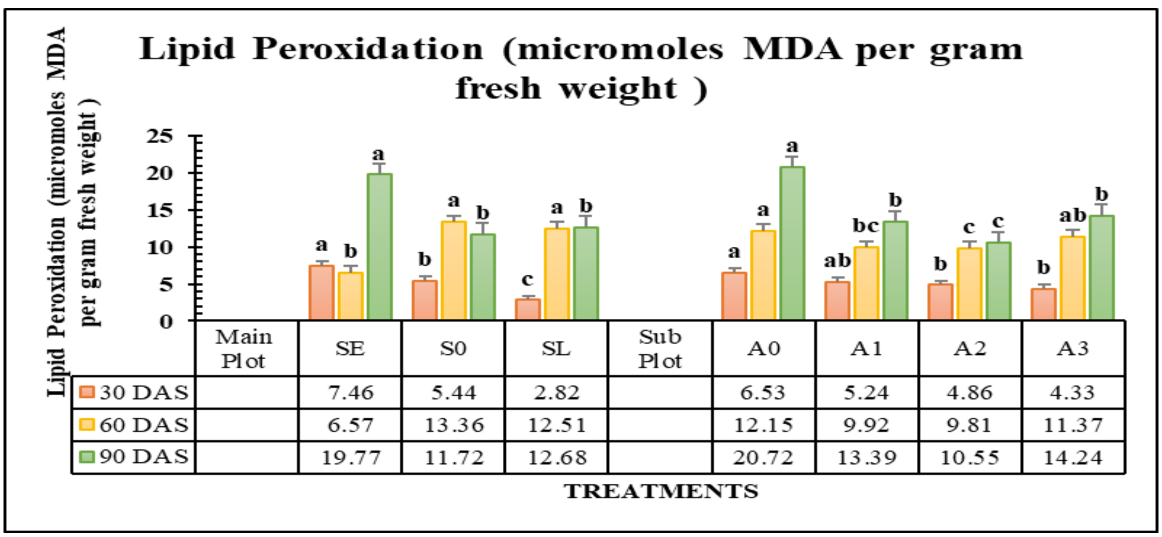
Treatments	Lipid peroxidation-2022			Lipid peroxidation-2023		
	30 DAS	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
SEA0	9.61^{a}±3.20	10.79^{a}±4.20	31.00^{a}±0.62	10.40^{a}±3.24	10.20^{hi}±2.17	31.71^{a}±0.63
SEA1	7.29^{ab}±0.97	9.30^{ab}±2.19	13.74^{cd}±1.18	8.08^{ab}±1.01	5.78^{def}±3.77	14.45^{cde}±1.22
SEA2	5.58^{bc}±0.82	2.69^{b}±2.30	12.71^{cde}±0.31	6.37^{bc}±0.92	3.58^{i}±2.28	13.42^{cde}±0.34
SEA3	3.88^{cdef}±0.16	5.53^{ab}±1.41	18.50^{b}±1.35	4.67^{cdef}±0.08	6.43^{gh}±1.40	19.21^{b}±1.22
S0A0	4.73^{bcd}±1.06	15.24a^{b}±0.88	14.67^{c}±0.85	5.55^{bcd}±1.17	16.14^{a}±0.86	15.38^{c}±0.98
S0A1	3.98^{cdef}±2.26	7.85^{ab}±1.81	11.37^{de}±2.10	4.77^{cdef}±2.13	8.75^{fg}±1.79	12.08^{def}±2.18
S0A2	4.52^{bcde}±0.44	12.71^{ab}±0.68	5.58^{f}±1.94	5.31^{bcde}±0.57	13.61^{abcd}±0.76	6.29^{g}±1.96
S0A3	5.06^{bcd}±1.78	13.74^{ab}±2.05	12.14^{cde}±1.99	5.86^{bcd}±1.67	14.64^{abc}±2.15	12.85^{cdef}±2.08
SLA0	2.64^{def}±0.54	14.05^{ab}±0.54	13.12^{cd}±2.59	3.43^{def}±0.40	14.95^{ab}±0.55	14.86^{cd}±1.66
SLA1	1.86^{ef}±1.53	9.04^{ab}±0.50	12.71^{cde}±1.83	2.65ef±1.63	9.94^{ef}±0.59	13.42^{cde}±1.73
SLA2	1.88^{ef}±0.70	11.11^{ab}±0.73	11.01^{de}±1.38	2.68^{ef}±0.73	12.01^{cde}±0.60	11.72^{ef}±1.51
SLA3	1.45^{f}±0.45	11.94^{ab}±1.55	9.71^{e}±2.42	2.24^{f}±0.40	12.83^{bcd}±1.43	10.42^{f}±2.55
CV	31.30	77.02	13.09	26.09	14.20	11.13
CD	2.80	16.15	3.00	2.85	3.01	2.81

Figure 4.2.12.1a. Effect of sowing dates and agrochemicals treatments on lipid peroxidation (micromoles MDA per gram fresh weight) of maize at 30, 60, and 90 DAS during spring season 2022



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		6.58	4.57	1.95		5.65	4.37	3.99	3.46
60 DAS		9.32	12.38	11.53		16.36	8.73	8.83	10.4
90 DAS		18.98	10.94	11.63		19.59	12.6	9.76	13.45

Figure 4.2.12.2b. Effect of sowing dates and agrochemicals treatments on lipid peroxidation (micromoles MDA per gram fresh weight) of maize at 30, 60, and 90 DAS during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		7.46	5.44	2.82		6.53	5.24	4.86	4.33
60 DAS		6.57	13.36	12.51		12.15	9.92	9.81	11.37
90 DAS		19.77	11.72	12.68		20.72	13.39	10.55	14.24

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.13 Catalase activity (mg/g fresh weight): The effect of different sowing dates and agrochemicals on Catalase activity (mg/g fresh weight) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was recorded at 30, 60, and 90 DAS (Table 4.2.13.1, 4.2.13.2 and Figure 4.2.13.1a, 4.2.13.2b). In 2022 and 2023, there was a significant difference in the percentage of Catalase activity (mg/g fresh weight) sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In agrochemicals, it was estimated by comparing all the standards with control. Thus, the percentage pattern in Catalase (mg/g fresh weight) was observed at 30, 60, and 90 DAS. In the year 2022, it was found that early sowing (SE) decreased the percentage by 0.85% and late sowing (SL) increased the rate by 4.44% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing (SE) increased the percentage by 0.65%, and late sowing decreased the rate by 7.46%, respectively. In the case of 90 DAS, the early sowing (SE) reduced the percentage by 4.82% and late sowing (SL) reduced the rate by 6.15% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 decreased the rate by 5.07%, A2 decreased by 0.71%, and A3 decreased the percentage by 0.66% as compared to control (A0) at 30 DAS. At 60 DAS, the rate decreased in A1 A2 and increased in A3 by 3.66%, 5.99%, and 6.49%, respectively, compared to the control. In the case of 90 DAS, the percentage decreased in A1 and increased in A2 and A3 by 1.75%, 1.40%, and 7.86%, respectively, compared to the control (A0). In the year 2023, the early sowing (SE) decreased the percentage by 0.86%, and the late sowing (SL) increased the rate by 4.49% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, early sowing (SE) increased the percentage by 0.64%, and late sowing decreased the rate by 7.52%. In the case of 90 DAS, the early sowing (SE) reduced the percentage by 4.88% and late sowing (SL) decreased the rate by 6.21% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 reduced the rate by 5.14%, A2 decreased by 0.68%, and A3 decreased the rate by 0.67% as compared to control (A0) at 30 DAS. At 60 DAS, the rate decreased in A1 and A2 and increased in A3 by 2.73%, 4.87%, and 7.22%, respectively, compared to the control. In the case of 90 DAS, the percentage decreased in A1 and increased in A2 and A3 by 1.77%, 1.38%, and 8.04%, respectively, compared to the control (A0). Catalase activity is an essential enzymatic process, providing insights into how plants adapt and react to diverse environmental stressors. This study aims to investigate the intricate mechanisms of catalase activity in crops subjected to untimely sowing, either before or after the recommended planting schedule. Understanding the fluctuations in catalase activity is crucial for comprehending the effects of environmental factors, timing of germination, and subsequent growth and reproductive processes. Sowing seeds at an early stage introduces a sequence of environmental stress factors that notably affect catalase activity in newly emerging seedlings. The potential disruption of cellular processes and induction of oxidative stress due to late spring frosts is a significant concern, highlighting the crucial involvement of the catalase enzyme. The impact of cold temperatures on vital physiological processes, such as the catalase function, has been observed to have discernible consequences on the overall health of plants. In the context of crops sown early, the reduction in catalase activity becomes a noteworthy issue, leading to heightened susceptibility to oxidative harm. Consequently, this impedes the plant's growth and developmental mechanisms. On the other hand, sowing crops later than usual brings about a specific range of environmental stress factors that intricately impact the catalase activity in crops. The compressed duration of the growing season places significant demands on plants to accelerate their vegetative and reproductive growth(Baranski et al., 2024; Xu et al., 2024; Jing and Huang 2024; Song et al., 2024; Basit et al., 2024; Herrera-Cabrera et al., 2024; Elsheikh and Eltanahy 2024; Li et al., 2024; Ademe et al., 2024; Pandey et al., 2024d; Dafny Yelin et al., 2024). During this tight period, there is a possibility of compromising catalase activity as plants accelerate through various growth stages, prioritising the allocation of resources towards reproductive activities. Time constraints limit the ability of crops to maximise their catalase activity. This highlights the intricate equilibrium necessary to attain an optimal catalase activity profile amidst fluctuating environmental stressors linked to deviations from the suggested sowing schedule. The timing of sowing is considered a crucial factor in the scientific investigation of catalase activity, as it determines the ideal conditions for crop growth and development. The synchronisation of this timing corresponds to advantageous environmental factors, such as temperature, soil moisture, and duration of daylight, all of which contribute to the optimal functioning of catalase. Synchronisation facilitates the prompt initiation of genetic and hormonal mechanisms, resulting in consistent and optimal levels of catalase activity. The suggested timing establishes the foundation for attaining an optimal enzymatic equilibrium, a crucial factor in determining the overall growth and productivity of the crop. To alleviate the influence of environmental stress on catalase activity, a strategic methodology is employed to investigate the involvement of growth regulators. Salicylic acid, well-known for its role in plant defence mechanisms, can be utilised for regulating catalase activity during unfavourable environmental circumstances. This strategic approach becomes especially pertinent for crops that are sown early, as it provides a method to enhance the resilience of plants against the potential adverse impacts of late frosts on the functioning of catalase. Salicylic acid's activation of stress response genes has been found to enhance the plant's capacity to endure environmental challenges, which may lead to a more consistent and optimal catalase activity profile(Baranski et al., 2024; Xu et al., 2024; Zhu and Huang 2024; Song et al., 2024; Basit et al., 2024; Herrera-Cabrera et al., 2024; Elsheikh and Eltanahy 2024; Dafny Yelin et al., 2024). In addition, using sodium nitroprusside, which acts as a donor of nitric oxide, offers an intervention to enhance catalase activity. When sodium nitroprusside is used carefully and deliberately, it impacts important physiological processes, such as the function of catalase, which is essential for the enzymatic processes it is involved in. This application facilitates the achievement of ideal catalase activity levels, which is particularly advantageous for crops planted late and must enhance both vegetative and reproductive growth despite a limited growing season. The intricate utilisation of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from the suggested sowing schedule. The investigation into the impact of environmental stress on catalase activity in crops provides a comprehensive comprehension of the complex interaction between timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops that are sown early encounter difficulties due to late frosts that hinder the optimal functioning of the enzyme catalase. On the other hand, crops that are planted late experience the stress of a shortened growing season, which affects various enzymatic processes. Establishing optimal conditions for achieving an ideal catalase activity profile is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies provides strategic interventions to improve crops' resilience. These interventions have the potential to impact catalase activity, as well as shape the overall enzymatic balance and productivity of the yield. This scientific investigation illuminates the environmental stress factors encountered by crops and offers deliberate interventions to address these challenges and enhance catalase activity for resilient crop growth.

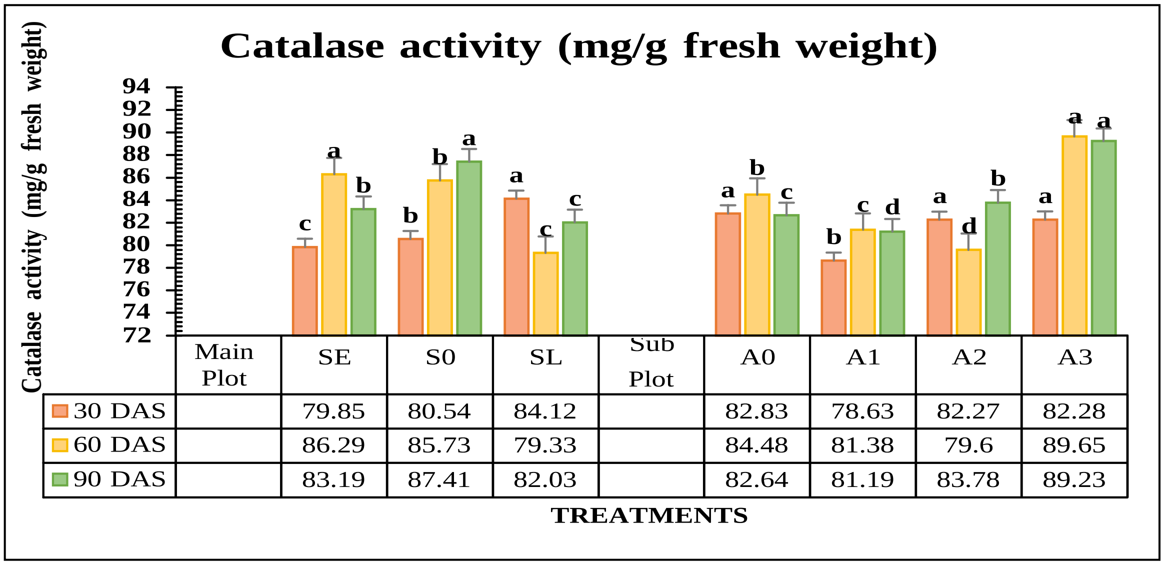
Table 4.2.13.1 Effect of sowing dates and agrochemicals treatments on catalase of maize (mg/g fresh weight) at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Catalase activity-2022			Catalase activity-2023		
At different Interval	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
(Sowing Date)						
SE -Early sowing	79.85	86.29	83.19	78.89	85.63	82.33
S0 -Optimum sowing	80.54	85.73	87.41	79.58	85.08	86.56
SL -Late sowing	84.12	79.33	82.03	83.16	78.68	81.18
(Agrochemicals)						
A0- Control	82.83	84.48	82.64	81.87	83.00	81.79
A1-Sodium nitroprusside (250 µM/L)	78.63	81.38	81.19	77.66	80.73	80.34
A2-Salicylic acid (150mg/L)	82.27	79.60	83.78	81.31	78.95	82.92
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	82.28	89.65	89.23	81.32	89.00	88.37
CV (Sowing)	0.34	0.44	1.05	0.35	0.44	1.06
CV (Sowing date and agrochemical)	0.79	0.62	0.78	0.80	0.62	0.79
CD (Sowing)	0.31	0.41	1.00	0.32	0.43	1.01
CD (Agrochemicals)	0.64	0.51	0.64	0.66	0.53	0.66

Table 4.2.13.2 The interaction effect of treatments on catalase activity of maize (mg/g fresh weight) at 30, 60, and 90 DAS during spring season 2022 and 2023

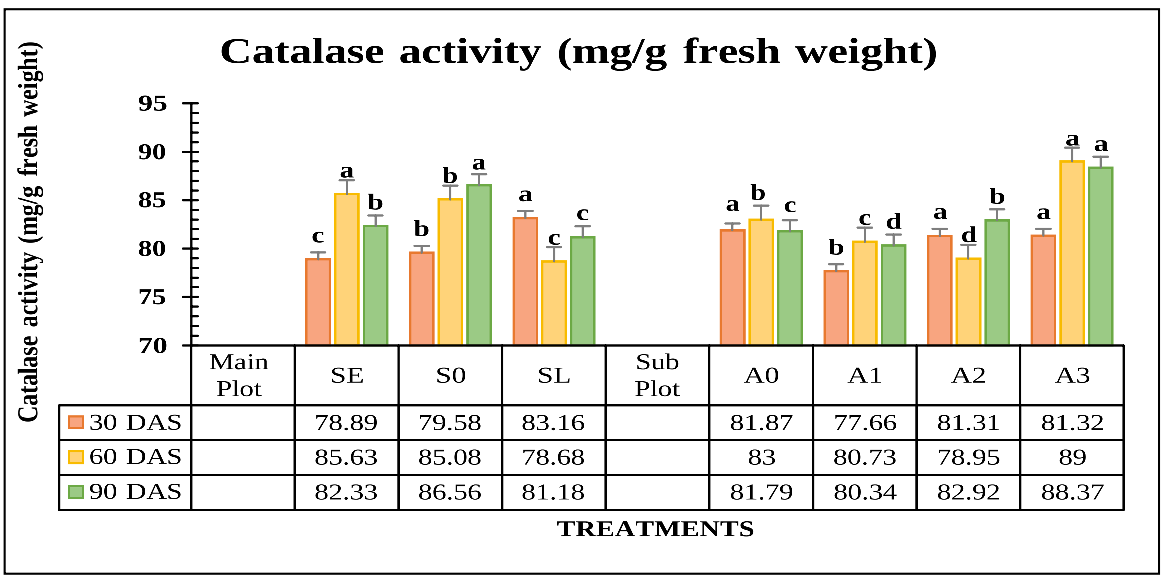
Treatments	Catalase activity-2022			Catalase activity-2023		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
SEA0	$84.42^{c}\pm0.85$	$90.40^{b}\pm0.17$	$80.24^{g}\pm0.15$	$83.50^{c}\pm0.78$	$89.79^{b}\pm0.18$	$79.43^{g}\pm0.10$
SEA1	$76.21^{g}\pm0.38$	$82.53^{d}\pm0.03$	$82.11^{e}\pm0.13$	$75.29^{g}\pm0.38$	$81.92^{d}\pm0.10$	$81.30^{e}\pm0.09$
SEA2	$76.24^{g}\pm0.11$	$80.20^{e}\pm0.59$	$80.82^{fg}\pm0.24$	$75.32^{g}\pm0.07$	$79.59^{e}\pm0.62$	$80.01^{fg}\pm0.24$
SEA3	$82.55^{d}\pm0.18$	$92.04^{a}\pm0.60$	$89.60^{b}\pm0.10$	$81.63^{d}\pm0.12$	$91.43^{a}\pm0.53$	$88.79^{b}\pm0.06$
S0A0	$79.40^{f}\pm1.41$	$82.96^{d}\pm0.05$	$83.27^{de}\pm0.12$	$78.47^{f}\pm1.33$	$82.35^{d}\pm0.12$	$82.46^{de}\pm0.14$
S0A1	$81.02^{e}\pm0.14$	$82.30^{d}\pm1.43$	$85.83^{c}\pm1.27$	$80.10^{e}\pm0.15$	$81.69^{d}\pm1.36$	$85.02^{c}\pm1.24$
S0A2	$86.10^{b}\pm0.17$	$87.25^{c}\pm0.14$	$88.59^{b}\pm0.28$	$85.18^{b}\pm0.20$	$86.64^{c}\pm0.17$	$87.78^{b}\pm0.26$
S0A3	$75.66^{g}\pm0.58$	$90.42^{b}\pm0.19$	$91.96^{a}\pm0.32$	$74.74^{g}\pm0.61$	$89.80^{b}\pm0.21$	$91.15^{a}\pm0.28$
SLA0	$84.70^{c}\pm0.07$	$80.10^{e}\pm0.25$	$84.44^{d}\pm0.12$	$83.78^{c}\pm0.04$	$79.49^{e}\pm0.24$	$83.63^{d}\pm0.06$
SLA1	$78.67^{f}\pm1.38$	$79.34^{e}\pm0.10$	$75.65^{h}\pm0.15$	$77.75^{f}\pm1.31$	$78.73^{e}\pm0.17$	$74.84^{h}\pm0.10$
SLA2	$84.48^{c}\pm0.08$	$71.37^{f}\pm0.12$	$81.93^{ef}\pm0.18$	$83.56^{c}\pm0.05$	$70.76^{f}\pm0.19$	$81.12^{ef}\pm0.11$
SLA3	$88.65^{a}\pm0.11$	$86.52^{c}\pm0.14$	$86.13^{c}\pm1.87$	$87.73^{a}\pm0.07$	$85.91^{c}\pm0.11$	$85.32^{c}\pm1.91$
CV	0.79	0.62	0.78	0.80	0.62	0.79
CD	1.00	0.87	1.38	1.01	0.88	1.37

Figure 4.2.13.1a. Effect of sowing dates and agrochemicals treatments on catalase of maize (mg/g fresh weight) at 30, 60, and 90 DAS during spring season 2022



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		79.85	80.54	84.12		82.83	78.63	82.27	82.28
60 DAS		86.29	85.73	79.33		84.48	81.38	79.6	89.65
90 DAS		83.19	87.41	82.03		82.64	81.19	83.78	89.23

Figure 4.2.13.2b. Effect of sowing dates and agrochemicals treatments on catalase of maize (mg/g fresh weight) at 30, 60, and 90 DAS during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		78.89	79.58	83.16		81.87	77.66	81.31	81.32
60 DAS		85.63	85.08	78.68		83	80.73	78.95	89
90 DAS		82.33	86.56	81.18		81.79	80.34	82.92	88.37

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.14 Total Starch (microgram/ml): The impact of different sowing dates and agrochemicals on Total Starch (microgram/ml) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS (Table 4.2.14.1, 4.2.14.2 and Figure 4.2.14.1a, 4.2.14.2b). In 2022 and 2023, there was a significant difference in the percentage of Total Starch (microgram/ml) sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates and case of agrochemicals; it was calculated by comparing all the standards with control. Thus, the percentage pattern in Total Starch (microgram/ml) was observed at 30, 60, and 90 DAS. In the year 2022, it was found that early sowing (SE) decreased the percentage by 83.49%, and late sowing (SL) increased the rate by 7.71% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing (SE) increased the percentage by 67.68%, and the late sowing decreased by 17.63%, respectively. In the case of 90 DAS, the early sowing (SE) reduced the percentage by 25.58% and late sowing (SL) decreased the rate by 14.61% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 increased the percentage by 13.33%, A2 increased by 4.67%, and A3 increased the percentage by 1.14% compared to control (A0) at 30 DAS. At 60 DAS, the rate increased in A1, A2, and A3 by 19.43%, 33.49%, and 9.70%, respectively, compared to the control. In the case of 90 DAS, the percentage increased in A1, whereas in A2 and A3, 28.54%, 42.67%, and 22.48%, respectively, compared to the control (A0). In the year 2023, the early sowing (SE) decreased the percentage by 83.33%, and the late sowing (SL) increased the rate by 7.69% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, early sowing (SE) increased the percentage by 67.31%, and late sowing decreased by 17.54%. In the case of 90 DAS, the early sowing (SE) reduced the percentage by 25.45% and late sowing (SL) reduced the rate by 12.96% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 increased the speed by 13.30%, A2 increased by 5.28%, and A3 increased the percentage by 1.20% as compared to control (A0) at 30 DAS. At 60 DAS, the rate increased in A1 and A2 and raised in A3 by 19.33, 39.78%, and 13.51%, respectively, compared to the control. In the case of 90 DAS, the percentage increased in A1, whereas it increased in A2 and A3 by 19.33%, 39.78%, and 13.51%, respectively, compared to the control (A0). Within the complex realm of crop physiology, the assessment of overall starch content is a significant indicator, offering valuable insights into the adaptive responses of plants to diverse environmental stressors. This study aims to investigate the intricate dynamics of total starch content in crops subjected to untimely sowing, either prematurely or delayed, compared to the planting schedule recommended by experts. Comprehending the fluctuations in overall starch concentration is crucial for elucidating the influence of environmental factors, timing of germination, and subsequent growth and reproductive processes. Sowing seeds at an early stage introduces a sequence of environmental stress factors that substantially impact the overall starch content found in newly emerging seedlings. The potential disruption of metabolic processes crucial for starch synthesis becomes evident due to the imminent threat of late spring frosts. Exposure to low temperatures has been found to disrupt essential physiological functions, thereby affecting the enzymatic activities involved in starch synthesis. In the context of crops sown early, the reduced total starch content becomes a noteworthy concern, as it can disrupt the equilibrium of energy reserves and hinder the overall growth and development of plants. On the other hand, the act of sowing crops late brings about a specific array of environmental stress factors that significantly impact the overall starch content in crops. The compressed duration of the growing season places significant demands on plants to accelerate their vegetative and reproductive growth. During this tight period, there is a possibility of a trade-off in the overall amount of starch present in plants as they expedite their growth stages and allocate resources towards reproductive processes. Their time constraints limit the ability of crops to maximize their general starch content. This highlights the importance of maintaining a precise equilibrium to attain an optimal starch content distribution in diverse environmental stressors linked to deviations from the suggested planting schedule. The timing of sowing is considered a crucial element in the scientific investigation of total starch content, as it determines the ideal conditions for crop growth and development. The timing of this phenomenon corresponds with advantageous environmental factors, such as optimal temperature, adequate soil moisture, and extended daylight duration, all of which contribute to the efficient process of starch synthesis. Synchronization facilitates the prompt initiation of genetic and hormonal mechanisms, resulting in consistent and optimal accumulation of total starch content. The suggested timing establishes the foundation for optimal metabolic equilibrium, a crucial factor influencing the crop's overall development and efficiency. To alleviate the effects of environmental stress on the general starch content, a strategic approach is employed to investigate the influence of growth regulators. Salicylic acid, well-known for its role in plant defence mechanisms, can regulate starch synthesis in unfavourable circumstances (Zhou et al., 2024; Tonon-Debiasi et al., 2024; Assad and Kumar 2024; Costa et al., 2024). The utilization of this strategic approach gains significance in the context of crops that are sown early, as it provides a method to enhance the resilience of plants against the potential adverse impacts of late frosts on the production of starch. Salicylic acid's activation of stress response genes has been found to enhance the plant's capacity to endure environmental challenges, thereby facilitating a more consistent and ideal total starch content profile. In addition, using sodium nitroprusside, which acts as a donor of nitric oxide, offers an intervention for enhancing overall starch content. When sodium nitroprusside is used carefully and deliberately, it impacts critical physiological processes, specifically starch synthesis, which is essential for the overall production of total starch content. This application aids in the determination of ideal starch levels, which is particularly advantageous for crops that are sown late and need to promote both vegetative and reproductive growth within a limited growing season. The intricate utilization of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from the recommended sowing schedule (Zhou et al., 2024; Tonon-Debiasi et al., 2024; Assad and Kumar 2024; Costa et al., 2024; Devkota et al., 2024; Wang et al., 2024; Javed et al., 2024; Su et al., 2024). The investigation into the impact of environmental stress on the overall starch content in crops provides a comprehensive comprehension of the complex interaction between timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops planted early encounter difficulties due to late frosts, which hinder the development of optimal starch content. Conversely, crops planted late experience the pressure of a shortened growing season, which affects their metabolic processes. Establishing optimal conditions for achieving an ideal total starch content profile is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions aimed at bolstering the resilience of crops. These interventions have the potential to impact starch levels, as well as influence the overall metabolic equilibrium and productivity of the crop. This scientific investigation illuminates the environmental stress factors encountered by crops. It presents a framework for strategic interventions to address these challenges and enhance overall starch content for resilient crop growth.

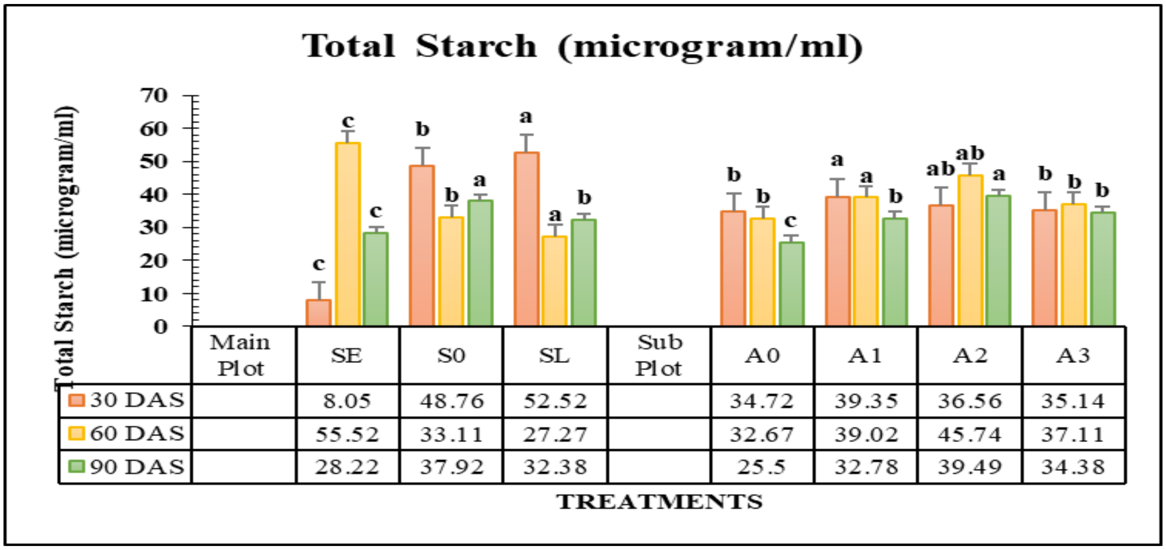
Table 4.2.14.1 Effect of treatments on total starch of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Total starch-2022			Total Starch-2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	8.05	55.52	28.22	8.14	55.70	28.40
S0 -Optimum sowing	48.76	33.11	37.92	48.85	33.29	38.10
SL -Late sowing	52.52	27.27	32.38	52.61	27.45	33.16
(Agrochemicals)						
A0- Control	34.72	32.67	25.50	34.81	32.85	32.85
A1-Sodium nitroprusside (250 µM/L)	39.35	39.02	32.78	39.44	39.20	39.20
A2-Salicylic acid (150mg/L)	36.56	45.74	39.49	36.65	45.92	45.92
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	35.14	37.11	34.38	35.23	37.29	37.29
CV (Sowing)	5.00	5.72	6.36	4.99	5.69	6.32
CV (Sowing date and agrochemical)	8.19	13.36	14.17	8.17	13.30	14.09
CD (Sowing)	2.06	2.50	2.38	2.03	2.52	2.33
CD (Agrochemicals)	2.95	5.11	4.63	2.89	5.16	4.59

Table 4.2.14.2 The interaction effect of treatments on total starch of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022 and 2023

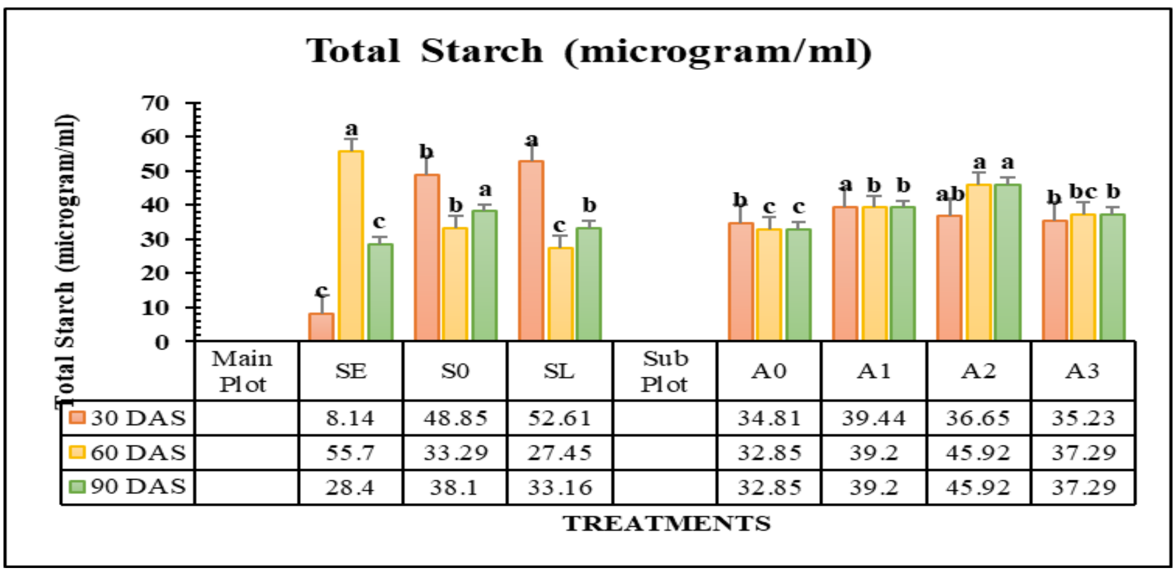
Treatments	Total starch-2022			Total starch-2023		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
SEA0	6.43^{f} ±0.61	50.14^{b} ±4.21	18.25^{f} ±0.64	6.52^{f}±0.61	50.32^{b}±4.21	18.43^{f}±0.64
SEA1	13.11^{e} ±8.26	51.71^{ab} ±0.43	24.88^{ef} ±0.30	13.20^{e}±8.26	51.89^{ab}±0.43	25.06^{ef}±0.30
SEA2	6.77^{f} ±1.11	60.31^{a} ±1.59	32.58^{cde} ±0.61	6.19^{f}±0.79	60.49^{a}±1.59	32.76^{cde}±0.61
SEA3	6.56^{f} ±0.89	59.95^{a} ±1.31	37.17^{bc} ±0.44	6.65^{f}±0.89	60.13^{a}±1.31	37.35^{bc}±0.44
S0A0	48.55^{cd} ±2.18	22.11^{ef} ±6.71	29.49^{cde} ±6.91	48.64^{cd}±2.18	22.29^{ef}±6.71	29.67^{cde}±6.91
S0A1	51.42^{abc} ±1.02	33.35^{cd} ±3.94	40.22^{ab} ±5.92	51.51^{abc}±1.02	33.53^{cd}±3.94	40.40^{ab}±5.62
S0A2	48.91^{bcd} ±1.93	39.73^{c} ±3.53	44.71^{a} ±2.24	49.00^{bcd}±1.93	39.91^{c}±3.53	44.89^{a}±2.24
S0A3	46.16^{d} ±0.67	37.29^{c} ±11.95	37.29^{abc} ±7.83	46.25^{d}±0.67	37.47^{c}±11.95	37.47^{abc}±7.83
SLA0	49.18^{bcd} ±3.88	25.79^{de} ±3.69	28.76^{de} ±0.80	49.27^{bcd}±3.88	25.97^{de}±3.69	28.94^{de}±0.80
SLA1	53.52^{ab} ±1.38	32.02^{cd} ±4.82	33.25^{bcd} ±7.95	53.61^{ab}±1.38	32.20^{cd}±4.82	33.43^{bcd}±7.95
SLA2	54.67^{a} ±0.45	37.18^{c} ±0.46	41.21^{ab} ±0.75	54.76^{a}±0.45	37.36^{c}±0.46	41.39^{ab}±0.75
SLA3	52.71^{abc}±0.36	14.10^{f} ±1.11	28.70^{de} ±0.58	52.80^{abc}±0.36	14.28^{f}±1.11	28.88^{de}±0.58
CV	8.19	13.36	14.17	8.17	13.30	14.09
CD	4.86	8.04	7.33	4.89	8.09	7.36

Figure 4.2.14.1a. Effect of sowing dates and agrochemicals treatments on total starch of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		8.05	48.76	52.52		34.72	39.35	36.56	35.14
60 DAS		55.52	33.11	27.27		32.67	39.02	45.74	37.11
90 DAS		28.22	37.92	32.38		25.5	32.78	39.49	34.38

Figure 4.2.14.2b. Effect of sowing dates and agrochemicals treatments on total starch of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		8.14	48.85	52.61		34.81	39.44	36.65	35.23
60 DAS		55.7	33.29	27.45		32.85	39.2	45.92	37.29
90 DAS		28.4	38.1	33.16		32.85	39.2	45.92	37.29

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.15 Total Amylopectin (microgram/ml): The impact of different sowing dates and agrochemicals on Total Amylopectin (microgram/ml) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was taken at 30, 60, and 90 DAS (Table 4.2.15.1, 4.2.15.2 and Figure 4.2.15.1a, 4.2.15.2b). In 2022 and 2023, there was a significant difference in the percentage of Total Amylopectin (microgram/ml) sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with control. Thus, the percentage pattern in Total Amylopectin (microgram/ml) was observed at 30, 60, and 90 DAS. In the year 2022, it was found that early sowing (SE) decreased the percentage by 85.85% and late sowing (SL) increased the rate by 10.35% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing (SE) increased the percentage by 92.91%, and the late sowing decreased by 9.11%. In the case of 90 DAS, the early sowing (SE) reduced the rate by 31.85%, and the late sowing (SL) increased the percentage by 11.83% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 increased the rate by 15.81%, A2 increased by 3.69%, and A3 increased the percentage by 1.83% as compared to control (A0) at 30 DAS. At 60 DAS, the rate increased in A1, A2, and A3 by 18.66%, 27.76%, and 6.58% respectively compared to the control. In the case of 90 DAS, the percentage increased in A1, whereas it increased in A2 and A3 by 27.22%, 44.41%, and 23.41%, respectively, compared to the control (A0). In the year 2023, the early sowing (SE) decreased the percentage by 85.95%, and the late sowing (SL) increased the rate by 10.38% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, early sowing (SE) increased the percentage by 92.53%, and late sowing decreased the rate by 9.09% respectively. In the case of 90 DAS, the early sowing (SE) reduced the percentage by 31.92%, and late sowing (SL) decreased the rate by 11.84% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 increased the speed by 15.87%, A2 increased by 4.29%, and A3 increased the percentage by 1.92% as compared to control (A0) at 30 DAS. At 60 DAS, the rate increased in A1, A2, and A3 by 18.48, 32.85%, and 8.73% respectively compared to the control. In the case of 90 DAS, the percentage increased in A1, whereas in A2 and A3, 27.24%, 56.55%, and 36.67%, respectively, compared to the control (A0). Within the complex realm of crop physiology, the assessment of overall amylopectin content emerges as a pivotal factor, providing significant insights into the adaptive responses of plants to various environmental stressors. This study examines the intricate interactions of total amylopectin content in crops exposed to untimely sowing before or after the recommended planting period. Comprehending the fluctuations in overall amylopectin content is crucial for elucidating the influence of environmental factors, timing of germination, and subsequent growth and reproductive processes. Sowing seeds at an early stage triggers a sequence of environmental stress factors that substantially impact the overall amylopectin content found in newly emerging seedlings. The potential disruption of the delicate balance of metabolic processes crucial for amylopectin synthesis becomes apparent due to the imminent threat of late spring frosts. The presence of cold temperatures hinders essential physiological processes, thereby affecting the enzymatic activities that are responsible for the production of amylopectin. In the context of crops sown early, the reduced total amylopectin content emerges as a notable issue, which can potentially disrupt the equilibrium of energy reserves and hinder the overall growth and development of plants. On the other hand, sowing crops late brings about a specific range of environmental stress factors that significantly impact the overall amylopectin content in the crops (Wencai Ren et al., 2024; Wang et al., 2024; Herrera-Cabrera et al., 2024; Jampílek and Kráľová 2024; Schasteen 2024; Kaushik et al., 2024; Akbari et al., 2024; Ademe et al., 2024). The compressed duration of the growing season places significant demands on plants to accelerate their vegetative and reproductive growth. During this compressed period, there is a possibility of a trade-off in the overall amylopectin content as plants accelerate their growth stages and allocate resources towards reproductive activities. The ability of crops to maximize their overall amylopectin content is limited by the time constraints they encounter. This highlights the intricate equilibrium necessary for optimal amylopectin composition amidst diverse environmental stressors linked to deviations from the prescribed sowing schedule. The timing of sowing is considered a crucial variable in the scientific investigation of total amylopectin content, as it determines the ideal conditions for crop growth and development. The timing of this phenomenon coincides with advantageous environmental factors, such as optimal temperature, adequate soil moisture, and sufficient daylight duration, all of which contribute to the efficient synthesis of amylopectin. Synchronization facilitates the prompt initiation of genetic and hormonal mechanisms, resulting in consistent and optimal levels of total amylopectin content. The suggested timing establishes the foundation for optimal metabolic equilibrium, a crucial crop development and efficiency factor. A systematic approach is employed to investigate the influence of growth regulators to address the adverse effects of environmental stress on the overall amylopectin content. Salicylic acid, well-known for its participation in plant defence mechanisms, can regulate amylopectin synthesis during unfavourable circumstances. This strategic approach becomes especially pertinent for crops that are sown early, as it provides a method to enhance the resilience of plants against the potential adverse impacts of late frosts on the production of amylopectin. Salicylic acid's activation of stress response genes has been found to enhance the plant's capacity to endure environmental challenges, which may contribute to a more consistent and ideal total amylopectin content profile. Moreover, the utilisation of sodium nitroprusside, which acts as a donor of nitric oxide, offers an intervention to maximise the overall amylopectin content. When sodium nitroprusside is used carefully and deliberately, it impacts important physiological processes, specifically the synthesis of amylopectin, which is essential for the overall production of amylopectin content (Yadav et al., 2023; Kumar and Pathak 2019; Kumar et al., 2019; Kotia et al., 2021; Kumar and Naik 2020; Hasnain et al., 2023). This application aids in achieving ideal levels of amylopectin, which is particularly advantageous for crops that are sown late and need to enhance both vegetative and reproductive growth despite a limited growing season. The intricate utilisation of these growth regulators showcases their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from the recommended sowing schedule. The investigation into the impact of environmental stress on the overall amylopectin content in crops provides a holistic comprehension of the complex interaction between timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops planted early encounter difficulties due to late frosts that hinder the achievement of an ideal amylopectin content. On the other hand, crops that are planted late experience the strain of a shortened growing season, which impacts their metabolic processes. Based on scientific principles, the timing of sowing is a crucial factor in creating the most favourable conditions for achieving an optimal profile of total amylopectin content. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions aimed at augmenting the resilience of crops. These interventions can potentially impact the amylopectin content and shape the crop's overall metabolic equilibrium and productivity. This scientific investigation not only elucidates the environmental stress factors encountered by crops but also offers a framework for strategic interventions to address these challenges and enhance total amylopectin content for resilient crop growth (Kumar et al., 2021; Singh and Kumar 2022; Chakraborty et al., 2021; Kumar and Dwivedi 2022; Pathak et al., 2018; Kumar et al., 2020; Siddique et al., 2018; Islam et al., 2023; Paul et al., 2005).

Table 4.2.15.1 Effect of treatments on amylopectin of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Amylopectin-2022			Amylopectin-2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	6.34	53.11	24.24	6.28	53.16	24.20
S0 -Optimum sowing	44.81	27.53	35.57	44.70	27.61	35.55
SL -Late sowing	49.45	25.02	31.36	49.34	25.10	31.34
(Agrochemicals)						
A0- Control	31.80	30.60	23.36	31.69	30.68	23.34
A1-Sodium nitroprusside (250 µM/L)	36.83	36.31	29.72	36.72	36.35	29.70
A2-Salicylic acid (150mg/L)	33.16	40.68	36.56	33.05	40.76	36.54
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	32.41	33.28	31.92	32.30	33.36	31.90
CV (Sowing)	3.81	23.78	5.21	3.82	23.66	5.22
CV (Sowing date and agrochemical)	8.63	21.26	15.48	8.66	21.23	15.49
CD (Sowing)	1.44	9.49	1.79	1.42	9.46	1.75
CD (Agrochemicals)	2.86	7.41	4.66	2.79	7.44	4.68

Table 4.2.15.2 The interaction effect of treatments on amylopectin of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Amylopectin-2022			Amylopectin-2023		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
SEA0	5.42^{f}±0.68	48.39^{ab}±4.34	15.07^{f}±0.39	5.22^{f}±0.55	48.38^{ab}±4.32	14.96^{f}±0.52
SEA1	10.72^{e}±7.22	49.57^{ab}±0.38	20.72^{ef}±0.48	10.53^{e}±7.26	49.45^{ab}±0.23	20.61^{ef}±0.62
SEA2	6.43^{f}±0.86	57.25^{a}±1.82	28.44^{de}±0.40	6.24^{f}±1.08	57.24^{a}±1.93	28.33^{de}±0.51
SEA3	5.00^{f}±1.42	57.26^{a}±1.10	32.73^{bcd}±0.76	4.81^{f}±1.48	57.25^{a}±1.22	32.63^{bcd}±0.76
S0A0	43.92^{cd}±2.56	19.32^{de}±6.27	27.45^{de}±6.67	43.73^{cd}±2.67	19.32^{de}±6.34	27.34^{de}±6.76
S0A1	48.44^{abc}±1.16	30.37^{cd}±3.59	37.37^{abc}±5.92	48.24^{abc}±1.06	30.36^{cd}±3.62	37.26^{abc}±5.99
S0A2	44.24^{cd}±2.16	36.37^{cd}±1.59	41.62^{a}±2.01	44.04^{cd}±2.11	29.70^{cd}±10.16	41.51^{a}±1.95
S0A3	42.66^{d}±1.03	44.06^{cd}±2.20	35.86^{abc}±8.07	42.47^{d}±1.16	40.72^{cd}±3.54	35.75^{abc}±8.00
SLA0	46.07^{bcd}±3.71	24.09^{cde}±2.90	27.57^{de}±0.94	45.87^{bcd}±3.77	24.09^{cde}±2.97	27.46^{de}±0.86
SLA1	51.35^{a}±1.08	29.01^{cd}±4.60	31.08^{cd}±7.66	51.15^{a}±1.16	29.00^{cd}±4.70	30.97^{abc}±7.73
SLA2	50.83^{ab}±0.60	35.11^{bc}±0.13	39.65^{ab}±0.90	50.63^{ab}±0.54	35.10^{bc}±0.26	39.54^{ab}±0.87
SLA3	49.57^{ab}±0.52	11.87^{e}±1.01	27.17^{de}±0.46	49.37^{ab}±0.51	11.87^{e}±1.16	27.06^{de}±0.36
CV	8.63	21.26	15.48	8.66	21.23	15.49
CD	4.52	14.49	7.20	7.21	14.46	4.54

Figure 4.2.15.1a. Effect of sowing dates and agrochemicals treatments on amylopectin of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2022

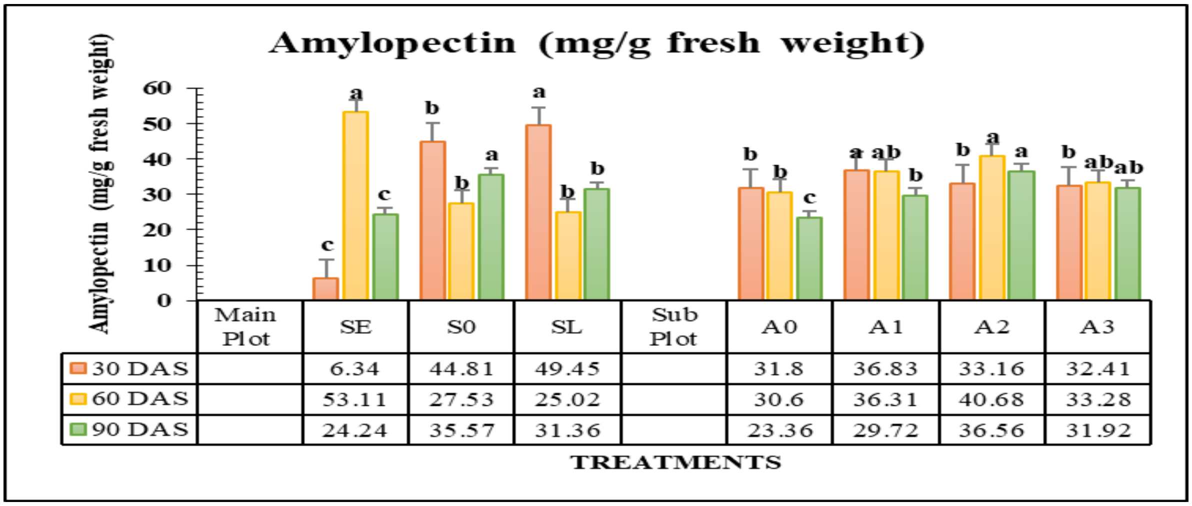
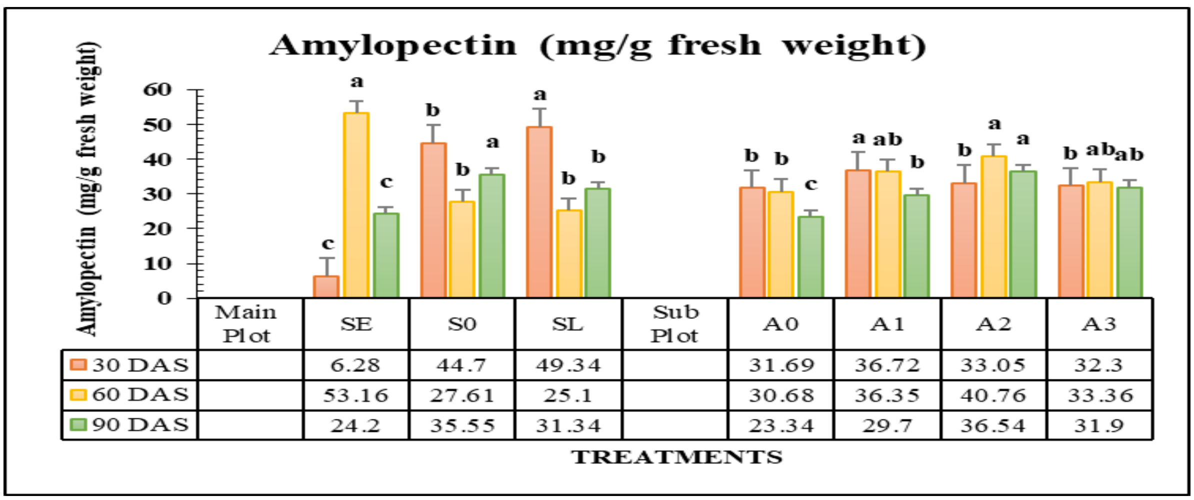


Figure 4.2.15.2b. Effect of sowing dates and agrochemicals treatments on amylopectin of maize (microgram/ml) at 30, 60, and 90 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.16 Membrane Stability Index (%): The impact of different sowing dates and agrochemicals on the Membrane Stability Index (%) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was recorded at 30, 60, and 90. DAS (Table 4.2.16.1, 4.2.16.2, and Figure 4.2.16.1a, 4.2.16.2b). In 2022 and 2023, there was a significant difference in the percentage of Membrane Stability Index (%) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in the case of different sowing dates. In the case of agrochemicals, it was calculated by comparing all the mean with the control. Thus, the percentage pattern in the Membrane Stability Index (%) was observed at 30, 60, and 90 DAS. In the year 2022, it was found that early sowing (SE) increased the percentage by 14.68%, and late sowing (SL) decreased the percentage by 3.67% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing (SE) decreased the percentage by 13.66%, and the late sowing decreased by 50.11%, respectively. In the case of 90 DAS, the early sowing (SE) decreased the percentage by 34.54%, and the late sowing (SL) decreased the percentage by 3.56% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 increased the percentage by 13.36%, A2 increased by 40.12%, and A3 increased by 22.00% compared to control (A0) at 30 DAS. At 60 DAS, the percentage increased in A1 and A2 and decreased in A3 by 20.18%, 18.90%, and 9.13%, respectively, compared to the control. In the case of 90 DAS, the percentage increased in A1, whereas in A2 and A3, by 69.84%, 41.80%, and 47.59%, respectively, compared to the control (A0). In the year 2023, the early sowing (SE) increased the percentage by 15.41%, and the late sowing (SL) decreased the percentage by 3.85% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, early sowing (SE) decreased the percentage by 14.45%, and late sowing decreased by 53.08%, respectively. In the case of 90 DAS, the early sowing (SE) decreased the percentage by 35.48%, and the late sowing (SL) decreased the percentage by 3.65% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 increased the percentage by 14.05%, A2 increased by 10.14%, and A3 increased the percentage by 46.21 % as compared to control (A0) at 30 DAS. At 60 DAS, the percentage increased in A1 and A2 and decreased in A3 by 21.82, 24.48%, and 12.16%, respectively, compared to the control. In the case of 90 DAS, the percentage increased in A1, whereas it increased in A2 and A3 by 73.20%, 74.41%, and 85.31%, respectively, compared to the control (A0). Evaluation of membrane stability index (MSI) concentration is a crucial parameter, offering significant perspectives on how plants react to various environmental stressors. This study investigates the intricate interactions of microsatellite instability (MSI) content in crops planted too early or too late instead of following the recommended planting schedule. Comprehending the diversities in MSI content is crucial to elucidate the influence of environmental factors, timing of germination, and subsequent growth and reproductive processes. Sowing seeds at an early stage introduces a range of environmental stress factors that substantially impact the content of microsatellite instability (MSI) in developing seedlings. The potential disruption of cellular membrane processes crucial for maintaining MSI is evident due to the imminent threat of late spring frosts. Exposure to low temperatures has been found to disrupt essential physiological processes, resulting in the impairment of cellular membrane integrity and a decrease in the content of MSI (membrane structural integrity). In the context of crops sown early in the growing season, the issue of compromised membrane sterol content (MSI) is a noteworthy concern. This compromise can disrupt the balance of membrane fluidity, negatively impacting the plants' overall growth and development. On the other hand, sowing crops later than usual presents a unique array of environmental stress factors that significantly impact the content of microsatellite instability (MSI) in crops. The compressed duration of the growing season places significant demands on plants to accelerate their vegetative and reproductive growth. During this compressed period, the content of MSI (Maternal Stress Induced) may be compromised as plants accelerate their growth stages and allocate resources towards reproductive activities (Kotia et al., 2021; Kumar and Naik 2020; Dwivedi and Kumar 2011; Pathak et al., 2017; Srivastav et al., 2023; Pathak, et al., 2018; Dwivedi et al., 2011a; Yumnam et al., 2018; Harshavardhan, et al., 2018; Kumar et al., 2018). Time constraints limit the ability of crops to maximize their MSI (micronutrient content). This highlights the intricate equilibrium necessary to attain an optimal membrane stability index amidst fluctuating environmental stressors linked to deviations from the prescribed sowing schedule. The timing of sowing is considered a crucial element in the scientific investigation of MSI content, as it determines the most favourable conditions for crop growth and development. The timing of this occurrence coincides with advantageous environmental factors, such as optimal temperature, soil moisture levels, and duration of daylight, all of which contribute to the effective maintenance of MSI. Synchronization facilitates the prompt initiation of genetic and hormonal mechanisms, resulting in consistent and optimal modulation of MSI content. The recommended timing establishes the foundation for attaining an optimal membrane stability index, which is a crucial factor in determining the overall growth and productivity of the crop. To address the adverse effects of environmental stress on MSI content, a strategic approach is employed to investigate the potential role of growth regulators. Salicylic acid, well-known for its participation in plant defence mechanisms, can be utilised for regulating membrane stability during unfavourable circumstances. The utilization of this strategic approach becomes especially pertinent for crops that are planted early, as it provides a method to enhance the resilience of plants against potential negative impacts of late frosts on the maintenance of multi-stress tolerance mechanisms. Salicylic acid's activation of stress response genes has been found to enhance the plant's capacity to endure environmental challenges, thereby facilitating a more consistent and optimal membrane stability index. In addition, the utilization of sodium nitroprusside, which acts as a donor of nitric oxide, offers an intervention aimed at optimizing the content of MSI. When sodium nitroprusside is used carefully and deliberately, it impacts important physiological processes, such as the stability of cell membranes, which is essential for preserving MSI content. This application plays a role in determining ideal MSI (Mean Soil Index) levels, which is particularly advantageous for crops sown late and aims to enhance both vegetative and reproductive growth despite the limitations imposed by a shortened growing season. The precise utilization of these growth regulators demonstrates their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from the recommended timing for sowing. In summary, the investigation into the impact of environmental stress on the content of membrane stability index in crops provides a holistic comprehension of the complex interaction between timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops that are sown early encounter difficulties due to late frosts, which hinder the attainment of optimal MSI (Membrane Stability Index) content. On the other hand, crops that are sown late experience the stress of a condensed growing season, which affects membrane processes. Establishing optimal conditions for achieving an ideal membrane stability index is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies provides strategic interventions to improve crops' resilience. These interventions can potentially influence the microsatellite instability (MSI) content and impact the yield's overall membrane stability and productivity. The present scientific investigation not only elucidates the environmental stressors encountered by crops but also offers a potential approach for targeted interventions to address these challenges and enhance the content of the membrane stability index, thereby promoting resilient crop growth(Kotia et al., 2021; Kumar and Naik 2020; Dwivedi and Kumar 2011; Pathak et al., 2017; Srivastav et al., 2023; Kumar et al., 2018; Mandal and Dwivedi 2011a; Yumnam et al., 2018; Kumar et al., 2018).

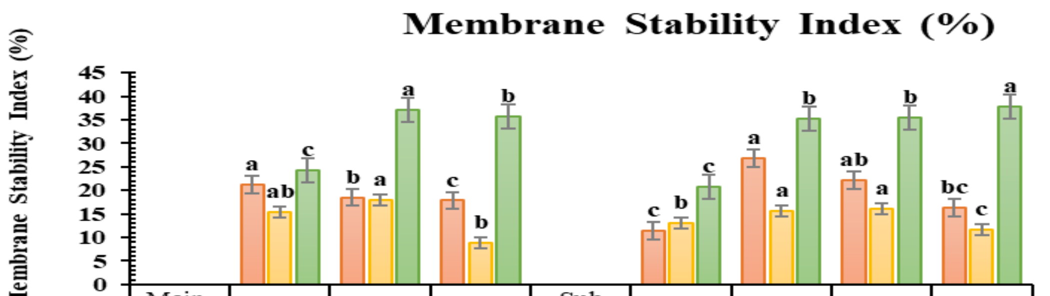
Table 4.2.16.1 Effect of treatments on membrane stability index (MSI) maize (%) at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Membrane stability index-2022			Membrane stability index-2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	21.24	15.42	24.25	20.36	14.44	23.27
S0 -Optimum sowing	18.52	17.86	37.05	17.64	16.88	36.07
SL -Late sowing	17.84	8.91	35.73	16.96	7.92	34.75
(Agrochemicals)						
A0- Control	11.46	13.03	20.79	10.58	12.05	19.82
A1-Sodium nitroprusside (250 µM/L)	26.80	15.66	35.31	25.93	14.68	34.33
A2-Salicylic acid (150mg/L)	22.18	15.99	35.55	21.31	15.00	34.57
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	16.34	11.57	37.71	15.47	10.59	36.73
CV (Sowing)	23.67	41.37	39.43	24.79	44.48	40.65
CV (Sowing date and agrochemical)	47.36	44.30	18.91	49.62	47.63	19.49
CD (Sowing)	5.15	6.59	14.45	5.12	6.55	14.48
CD (Agrochemicals)	9.00	6.17	6.05	9.01	6.19	6.02

Table 4.2.16.2 The interaction effect of treatments on membrane stability index (MSI) of maize (%) at 30, 60, and 90 DAS during spring season 2022 and 2023

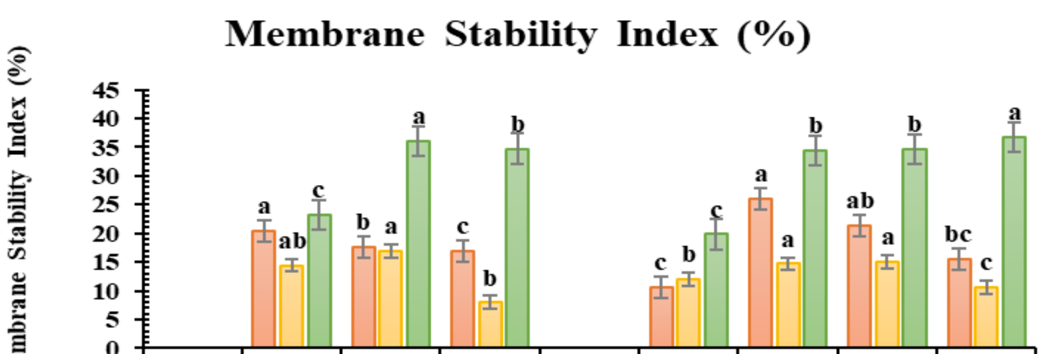
Treatments	Membrane Stability Index-2022			Membrane Stability Index-2023		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
SEA0	4.53^{c}±4.41	12.28^{abc}±5.11	17.50^{g}±4.73	4.74^{c} ±4.31	12.49^{abc} ±4.99	17.38^{h} ±4.81
SEA1	33.87^{a}±2.82	16.00^{abc}±2.21	22.69^{e}±9.38	34.08^{a} ±2.69	16.21^{abc} ±2.07	22.90 ^{f}±9.47
SEA2	21.99^{ab}±13.34	18.67^{ab}±1.94	22.24^{e}±11.42	22.20^{ab} ±13.20	18.87^{ab} ±1.82	22.45^{f} ±11.53
SEA3	21.08^{ab}±12.81	10.84^{abc}±2.02	34.67^{c}±2.42	21.29^{ab} ±12.95	11.05^{abc} ±2.00	34.88^{d} ± 2.50
S0A0	13.46^{bc}±10.85	18.42^{ab}±10.82	19.13^{f}±4.86	13.67^{bc} ±10.84	18.63 ^{ab}±10.82	19.33^{g} ±4.96
S0A1	22.69^{ab}±2.22	28.00^{a}±1.89	45.11^{a}±13.92	22.90^{ab} ±2.35	28.21^{a} ±2.00	45.32^{a} ±14.00
S0A2	18.13^{bc}±8.39	17.85^{ab}±3.68	46.19^{a}±9.01	18.34^{bc} ±8.34	18.06^{ab} ±3.65	46.40^{a} ±9.07
S0A3	16.30^{bc}±7.92	10.92^{abc}±3.21	33.88^{bc}±4.25	16.51^{bc} ±7.90	11.13^{abc} ±3.34	34.09^{d} ±4.36
SLA0	13.77^{bc}±10.22	5.45^{c}±1.52	26.84^{d}±7.99	13.98^{bc} ±10.25	5.66^{c} ±1.37	27.05^{e} ±8.10
SLA1	21.25^{ab}±5.48	7.72^{bc}±0.61	35.21^{c}±3.93	21.46^{ab} ±5.38	7.93^{bc} ±0.72	35.42^{c}±4.07
SLA2	23.81^{ab}±3.15	8.51^{bc}±2.43	35.30^{bc}±13.85	24.02^{ab} ±3.04	8.72^{bc} ±2.29	35.51^{c} ±13.99
SLA3	9.04^{bc}±5.68	10.03^{abc}±0.48	41.66^{b}±9.57	9.24^{bc} ±5.76	10.24^{abc} ±0.62	41.87^{b} ±9.65
CV	47.36	44.30	18.91	49.62	47.63	19.49
CD	16.92	11.28	14.40	16.95	11.25	14.45

Figure 4.2.16.1a. Effect of sowing dates and agrochemicals treatments on membrane stability index (MSI) maize (%) at 30, 60, and 90 DAS during spring season 2022



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		21.24	18.52	17.84		11.46	26.8	22.18	16.34
60 DAS		15.42	17.86	8.91		13.03	15.66	15.99	11.57
90 DAS		24.25	37.05	35.73		20.79	35.31	35.55	37.71

Figure 4.2.16.2b. Effect of sowing dates and agrochemicals treatments on membrane stability index (MSI) maize (%) at 30, 60, and 90 DAS during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
30 DAS		20.36	17.64	16.96		10.58	25.93	21.31	15.47
60 DAS		14.44	16.88	7.92		12.05	14.68	15	10.59
90 DAS		23.27	36.07	34.75		19.82	34.33	34.57	36.73

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.2.17 Membrane Injury Index (%): The impact of different sowing dates and agrochemicals on the Membrane Injury Index (%) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data was recorded at 30DAS, 60 DAS, and 90 DAS (Table 4.2.17.1, 4.2.17.2 and Figure 4.2.17.1a, 4.2.17.2b). In 2022 and 2023, there was a significant difference in the percentage of Membrane Injury Index (%) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was calculated by comparing all the mean with control. Thus, the percentage pattern in the Membrane Injury Index (%) was observed at 30, 60, and 90 DAS. In the year 2022, it was found that early sowing (SE) decreased the percentage by 3.35%, and late sowing (SL) increased the percentage by 0.83% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing (SE) increased the percentage by 2.97%, and the late sowing increased by 10.89%, respectively. In the case of 90 DAS, the early sowing (SE) increased the percentage by 20.33%, and the late sowing (SL) increased the percentage by 2.11% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 decreased the percentage by 17.32%, A2 decreased by 14.64%, and A3 decreased the percentage by 6.27% as compared to control (A0) at 30 DAS. At 60 DAS, the percentage decreased in A1 and A2 and increased in A3 by 3.02%, 3.49%, and 1.73%, respectively, compared to the control. In the case of 90 DAS, the percentage decreased in A1, whereas it decreased in A2 and A3 by 18.33%, 22.82%, and 26.25%, respectively, compared to the control (A0). In the year 2023, the early sowing (SE) decreased the percentage by 3.03%, and the late sowing (SL) increased the percentage by 0.85% as compared to optimum sowing (S0) at 30 DAS. At 60 DAS, early sowing (SE) increased the percentage by 2.92%, and late sowing increased by 10.76%, respectively. In the case of 90 DAS, the early sowing (SE) increased the percentage by 20.02%, and the late sowing (SL) increased the percentage by 2.06% as compared to the optimum sowing (S0). Among the applied agrochemicals, A1 decreased the percentage by 17.16%, A2 decreased by 12.69%, and A3 decreased the percentage by 5.45% as compared to control (A0) at 30 DAS. At 60 DAS, the percentage decreased in A1 and A2 and increased in A3 by 2.99%, 3.35%, and 1.66%, respectively, compared to the control. In the case of 90 DAS, the percentage decreased in A1, A2, and A3 by 18.09%, 18.39%, and 21.09%, respectively, compared to the control (A0). The assessment of membrane injury index (MII) content plays a crucial role as a significant measure, providing valuable insights into the plant's response to various environmental stressors. This study examines the intricate interactions of MII content in crops that are sown either too early or too late instead of following the recommended planting timetable. Comprehending the diversities in MII content holds significant importance in elucidating the influence of environmental factors, timing of germination, and subsequent growth and reproductive processes. Sowing seeds at an early stage triggers a series of environmental stress factors that substantially affect the content of MII (maturation and initiation of germination) in newly emerging seedlings. The potential disruption of cellular membrane processes crucial for MII maintenance becomes apparent due to the imminent threat of late spring frosts. Exposure to low temperatures has a detrimental effect on essential physiological functions, causing a disruption in the integrity of cellular membranes and resulting in an increase in MII content. Within the framework of early-sown crops, the increased presence of MII content emerges as a significant issue, which can disrupt the equilibrium of membrane fluidity and hinder the overall progress of plant growth and development. On the other hand, sowing crops later than usual brings forth a specific array of environmental stress factors that significantly impact the content of MII (metabolically essential ingredients) in the crops(Pramanik et al., 2023; Avinash Sharma et al., 2023; Sánchez-Castro et al., 2023; Hasnain et al., 2023; Mandal et al., 2023; Zhang et al., 2023; Boamah et al., 2023; Geetha et al., 2023; Omidvari et al., 2023; Mahawar et al., 2023; Ain et al., 2023; Wu et al., 2023). The compressed duration of the growing season places significant demands on plants to accelerate their vegetative and reproductive growth. Increased MII content is possible during this compressed period as plants expedite their growth stages and allocate resources towards reproductive activities. The ability of crops to maximise their metabolically essential ingredient (MII) content is limited by time constraints. This highlights the intricate equilibrium necessary to attain an optimal membrane injury index in light of diverse environmental stressors linked to deviations from the suggested sowing schedule. The timing of sowing is considered a crucial element in the scientific investigation of MII content, as it determines the ideal conditions for the growth and development of crops. The timing of this event coincides with advantageous environmental factors such as temperature, soil moisture, and duration of daylight, all of which contribute to the effective maintenance of MII. Synchronisation facilitates the prompt initiation of genetic and hormonal mechanisms, resulting in consistent and optimal maturation of MII content. The suggested timing establishes the foundation for attaining an optimal membrane injury index, a critical factor influencing the crop's overall growth and productivity. A strategic approach is employed to investigate the potential influence of growth regulators to address the adverse effects of environmental stress on MII content. Salicylic acid, well-known for its role in plant defence mechanisms, can be utilised to regulate membrane stability in the face of unfavourable circumstances. This strategic approach is especially significant for crops that are planted early, as it provides a method to enhance the resilience of plants against potential negative impacts caused by late frosts on the maintenance of MII. Salicylic acid's activation of stress response genes has been found to enhance the plant's capacity to endure environmental challenges, thereby facilitating a more consistent and optimal membrane injury index. In addition, the utilisation of sodium nitroprusside, which acts as a donor of nitric oxide, offers an intervention to optimise the content of metaphase II. When used carefully and deliberately, sodium nitroprusside impacts critical physiological processes, such as membrane stability, essential for preserving MII content. This application plays a role in determining ideal MII (Management Inputs) levels, which is particularly advantageous for crops sown late and facing the challenge of achieving accelerated vegetative and reproductive growth within a limited growing period. The intricate utilisation of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from suggested sowing schedules. In summary, the investigation into the impact of environmental stress on the content of membrane injury index in crops provides a holistic comprehension of the complex interaction between timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops planted early encounter difficulties due to late frosts that hinder the attainment of optimal MII (membrane integrity index) content. On the other hand, crops that are planted late experience the strain of a condensed growing season, which impacts membrane processes. Establishing optimal conditions for achieving an ideal membrane injury index is heavily influenced by the recommended sowing timing, which is based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions for improving the resilience of crops. These interventions can potentially impact the content of major intrinsic proteins and influence the overall stability of cell membranes, thereby enhancing crop productivity. This scientific investigation not only elucidates the environmental stress factors encountered by crops but also offers a framework for targeted interventions to address these challenges and enhance the content of the membrane injury index for resilient crop growth (Kumar et al., 2019; Siddique et al.,2018).

Table 4.2.17.1 Effect of treatments on membrane injury index (MII) of maize (%) at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Membra injury index-2022			Membra injury index-2023		
At different Interval	**30 DAS**	**60 DAS**	**90 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
(Sowing Date)						
SE -Early sowing	78.75	84.57	75.74	79.63	85.55	76.72
S0 -Optimum sowing	81.48	82.13	62.94	82.35	83.12	63.92
SL -Late sowing	82.16	91.08	64.27	83.03	92.07	65.24
(Agrochemicals)						
A0- Control	88.53	86.96	79.20	89.41	87.94	80.17
A1-Sodium nitroprusside (250 µM/L)	73.19	84.33	64.68	74.06	85.31	65.66
A2-Salicylic acid (150mg/L)	77.81	84.01	64.44	78.06	84.99	65.42
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	83.65	88.42	62.28	84.53	89.40	63.26
CV (Sowing)	5.62	6.77	18.85	5.56	6.70	18.58
CV (Sowing date and agrochemical)	11.25	7.25	9.04	11.13	7.17	8.91
CD (Sowing)	5.15	6.59	14.45	5.12	6.52	14.39
CD (Agrochemicals)	9.00	6.17	6.05	9.01	6.15	6.08

Table 4.2.17.2 Interaction effect treatments on membrane injury index (MII) of maize (%) at 30, 60, and 90 DAS during spring season 2022 and 2023

Treatments	Membra injury index-2022			Membra injury index-2023		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
SEA0	95.18^{a}±4.09	87.68^{abc}±5.06	86.79^{a}±10.84	95.26^{a}±4.31	87.51^{abc}±4.99	82.62^{a}±4.81
SEA1	66.11^{c}±2.79	84.13^{abc}±2.43	77.23^{c}±9.47	65.92^{c}±2.69	83.79^{abc}±2.07	77.10^{b}±9.47
SEA2	78.01^{bc}±13.25	81.35^{bc}±1.96	77.82^{c}±11.33	77.80^{bc}±13.20	81.13^{bc}±1.82	77.55^{b}±11.53
SEA3	78.92^{bc}±12.81	89.07^{abc}±2.00	65.22^{e}±2.53	78.71^{bc}±12.95	88.95^{abc}±2.00	65.12^{c}±2.50
S0A0	86.49^{ab}±10.84	81.56^{bc}±10.82	81.04^{b}±4.67	86.33^{ab}±10.84	81.37^{bc}±10.82	80.67^{a}±4.96
S0A1	77.31^{bc}±2.22	79.56^{c}±15.24	54.94^{h}±13.88	77.10^{bc}±2.35	71.79^{c}±2.00	54.68^{c}±14.00
S0A2	81.96^{ab}±8.46	82.37^{bc}±3.76	53.68$^{i.}$±9.11	81.66^{ab}±8.34	81.94^{bc}±3.65	53.60^{c}±9.07
S0A3	83.70^{ab}±7.92	88.88^{abc}±3.54	66.23^{e}±4.10	83.49^{ab}±7.90	88.87^{abc}±3.34	65.91^{c}±4.36
SLA0	86.32^{ab}±19.19	94.77^{a}±1.90	73.39^{d}±7.69	86.02^{ab}±10.25	94.34^{a}±1.37	72.95±8.10
SLA1	78.87^{bc}±5.63	92.21^{ab}±0.70	64.81^{f}±3.89	78.54^{bc}±5.38	92.07^{ab}±0.72	64.58^{cd}±4.07
SLA2	76.13^{bc}±3.07	91.43^{ab}±2.33	64.78^{f}±13.72	75.98^{bc}±3.04	91.28^{ab}±2.29	64.49^{cd}±13.99
SLA3	90.73^{ab}±5.89	89.95^{abc}±0.52	58.33^{g}±9.57	90.76^{ab}±5.76	89.76^{abc}±0.62	58.13^{d}±9.65
CV	11.25	7.25	9.04	11.13	7.17	8.91
CD	16.92	11.28	14.40	16.99	11.26	14.42

Figure 4.2.17.1a. Effect of sowing dates and agrochemicals treatments on membrane injury index (MII) of maize leaves (%) at 30, 60, and 90 DAS during spring season 2022

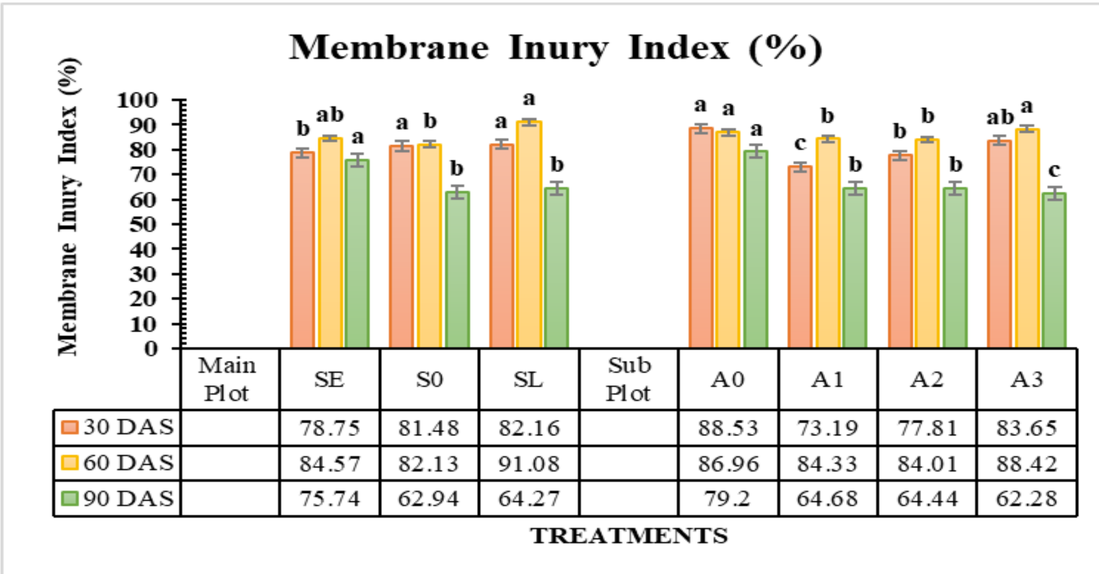
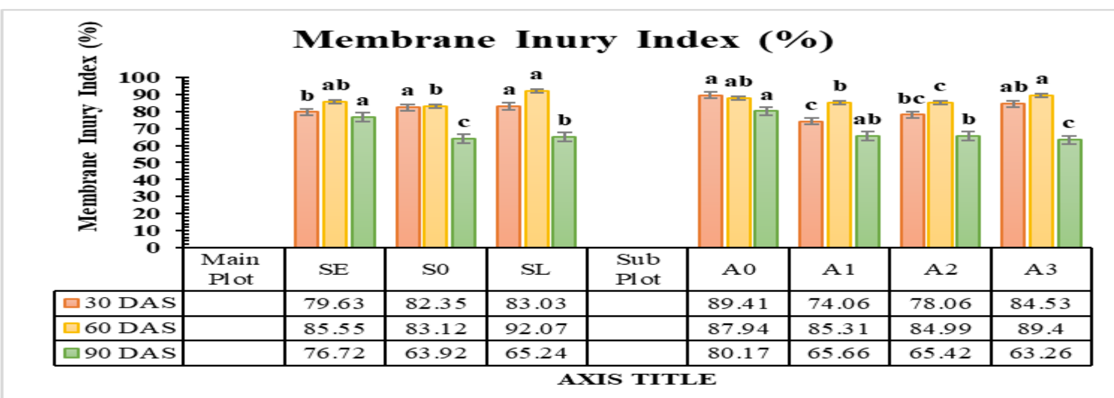


Figure 4.2.17.2b. Effect of sowing dates and agrochemicals treatments on membrane injury index (MII) of maize leaves (%) at 30, 60, and 90 DAS during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.3 Yield attributes

4.3.1 Number of cobs/plants: The impact of different sowing dates and agrochemicals on the Number of cobs/plants at harvest is shown in (Table 4.3.1.1 4.3.1.2 and Figure 4.3.1.1a, 4.3.1.2b). In 2022 and 2023, there was a significant difference in the Number of cobs/plant sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with the control. Thus, the percentage pattern in the Number of cobs/plants was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 13.08%, and in late sowing, it decreased by 13.09% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) reduced the percentage by 6.62% when it was compared to the control (A0). The application of salicylic acid (A2) showed a better result by increasing the rate by 21.93% compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the rate by 5.50% compared to the control (A0). In 2023, it was also found that early sowing (SE) decreased the percentage by 17.00% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate decreased by 12.50% compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) increased the percentage by 6.62% compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 20.48% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 6.45% compared to the control (A0). In crop physiology, the assessment of cob count per plant holds significant importance as a critical metric, offering valuable insights into the response of plants to various environmental stress factors. This study investigates the intricate dynamics of cob quantity per plant in crops subjected to untimely sowing, either prematurely or delayed, in contrast to the recommended planting schedule. Gaining insight into the fluctuations in the number of cobs per plant is crucial to comprehend the effects of environmental factors, the timing of germination, and subsequent growth and reproductive processes. Sowing seeds at an early stage initiates a sequence of environmental stress factors that substantially impact the quantity of cobs produced by each plant in the initial stages of growth. The potential disruption of the delicate balance of reproductive processes crucial for cob development becomes evident due to the imminent threat of late spring frosts. The presence of low temperatures has a disruptive effect on essential physiological mechanisms, resulting in the impairment of flower bud differentiation and compromising the formation of cobs. Within the framework of early-sown crops, the issue of a decreased quantity of cobs per individual plant emerges as a significant matter of concern, which can lead to a decline in overall crop yield and hinder the overall growth and development of the plants (Silva et al., 2024; He et al., 2024; Wang et al., 2024; Agus et al., 2024; Nyfeler et al., 2024; Umair et al., 2024; Begum et al., 2024; Wei et al., 2024; Wang et al., 2024; Li et al., 2024; Aggarwal et al., 2024; Srivastava and Gupta 2024). On the other hand, sowing crops later than usual introduces a unique array of environmental stressors that intricately impact the number of cobs per plant. The compressed duration of the growing season places significant demands on plants to accelerate their vegetative and reproductive growth. During this abbreviated period, there exists the possibility of a decrease in the number of cobs produced per plant as the plants expedite their progression through various growth phases, allocating resources towards reproductive endeavours. Time constraints limit the ability of crops to maximise their cob production. This highlights the intricate equilibrium necessary to attain optimal cobs per plant amidst diverse environmental stressors linked to deviations from the suggested sowing schedule. The timing of sowing is considered a crucial element in the scientific investigation of cob yield per plant, as it determines the ideal conditions for crop growth and development. The timing of this phenomenon coincides with advantageous environmental factors, such as optimal temperature, soil moisture, and duration of daylight, all of which contribute to the efficient development of maize cobs. Synchronisation facilitates the timely initiation of genetic and hormonal mechanisms, resulting in consistent and optimal cob production. The suggested timing establishes the foundation for attaining an optimal quantity of cobs per plant, which is a crucial factor in determining the overall growth and productivity of the crop (Agregán et al., 2024; Singh et al., 2024; Zhou et al., 2024; Liu and Moy 2024; Tonon-Debiasi et al., 2024). To address the influence of environmental stress on cob production per plant, a strategic approach is employed to investigate the potential impact of growth regulators. Salicylic acid, well-known for its participation in plant defence mechanisms, can potentially be utilised for regulating reproductive processes in unfavourable environments. This strategic approach becomes especially pertinent for crops that are planted early, as it provides a method to enhance the resilience of plants against the potential adverse impacts of late frosts on the development of cobs. The activation of stress response genes by salicylic acid has been found to enhance the plant's capacity to endure environmental challenges, thereby facilitating a more consistent and optimal yield of cobs per plant. In addition, using sodium nitroprusside, which acts as a donor of nitric oxide, offers an intervention to maximise the number of cobs produced per plant. When sodium nitroprusside is applied carefully and deliberately, it influences vital physiological processes, such as flower bud differentiation, which is essential for developing cobs. This application aids in determining the ideal cob levels, which is particularly advantageous for crops sown late and need to accelerate their reproductive growth despite having a shorter growing season. The intricate utilisation of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from the recommended sowing schedule. The investigation into the impact of environmental stress on crop yield, precisely the number of cobs per plant, provides a holistic comprehension of the complex dynamics involving timing, growth conditions, and the development of both vegetative and reproductive aspects (Álvaro-Fuentes, and Cantero-Martínez 2024; Mehmood et al., 2024; Zeb et al., 2024; Pandey et al., 2024b; Mansilla et al., 2024;Singh et al., 2024; Rajabi and Haghparast 2024; Orek 2024; Oberkofler and Glandorf 2024; Bhuyan and Deka 2024; Kozeko et al., 2024; Zhan et al., 2024; Hefft and Adetunji 2024). Crops planted early encounter difficulties due to late frosts that hinder the ideal result of their cobs. On the other hand, crops that are planted late experience the strain of a shortened growing season, which affects their reproductive processes. Establishing optimal conditions for achieving an ideal number of cobs per plant is contingent upon adhering to scientifically derived recommendations regarding sowing timing. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions that can effectively bolster the resilience of crops. These interventions have the potential to impact cob production, as well as shape the overall growth and productivity of the crop. This scientific investigation illuminates the environmental stressors encountered by crops. It offers a framework for strategic interventions to address these challenges and enhance the yield of cobs per plant for optimal crop growth.

Table 4.3.1.1 Effect of treatments on the number of cobs of maize at harvest during the spring season 2022 and 2023

Treatments	Number of cobs-2022	Number of cobs-2023
Sowing Date		
SE -Early sowing	1.66	1.66
S0 -Optimum sowing	1.91	2.00
SL -Late sowing	1.66	1.75
Agrochemical		
A0- Control	1.66	1.66
A1-Sodium nitroprusside (250 µM/L)	1.77	1.55
A2-Salicylic acid (150mg/L)	1.55	1.77
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	2.00	2.00
Alpha at 0.05	1.77	1.77
CV (Sowing date and agrochemical)	27.49	25.56
CV (Sowing)	20.20	9.23
CD (Agrochemical)	0.40	0.18
CD (Sowing)	0.47	0.45

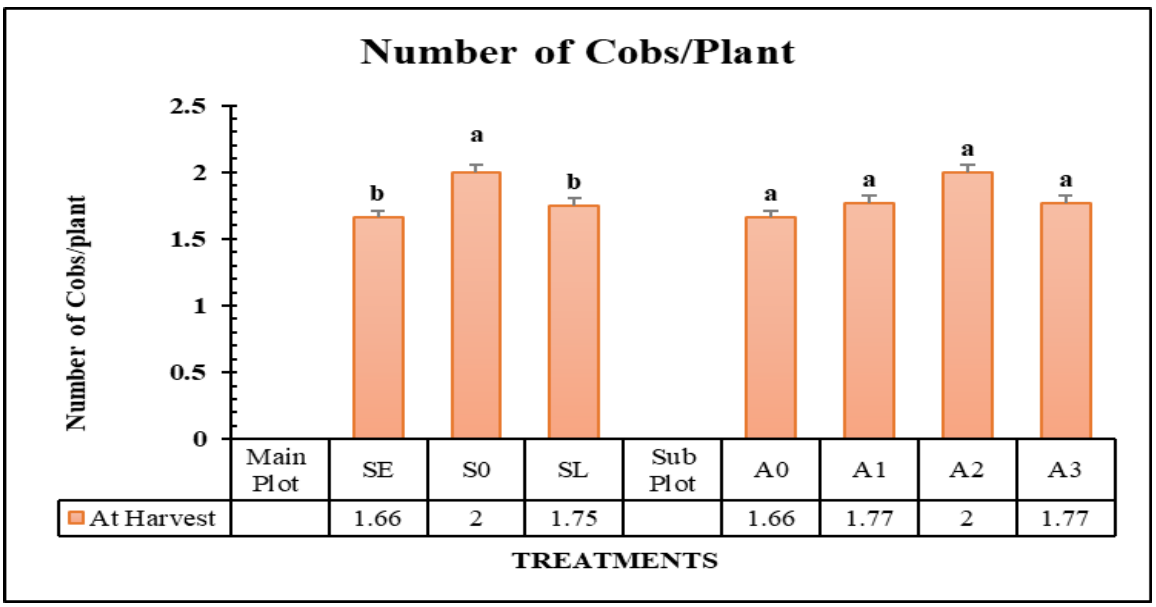
Table 4.3.1.2 The interaction effect of treatments on the number of cobs of maize at harvest during Spring Season 2022 and 2023

Treatments	Number of cobs-2022	Number of cobs-2023
SEA0	1.33^{a}±0.58	1.33^{a}±0.58
SEA1	1.33^{a}±0.58	1.67^{a}±0.58
SEA2	2.33^{a}±0.58	2.00^{a}±0.00
SEA3	1.67^{a}±0.58	1.67^{a}±0.58
S0A0	1.67^{a}±0.58	2.00^{a}±0.00
S0A1	1.67^{a}±0.58	1.67^{a}±0.58
S0A2	1.67^{a}±0.58	2.00^{a}±0.00
S0A3	1.67^{a}±0.58	2.00^{a}±0.00
SLA0	1.67^{a}±0.58	1.67^{a}±0.58
SLA1	1.67^{a}±0.58	1.33^{a}±0.58
SLA2	2.33^{a}±0.58	2.00^{a}±0.00
SLA3	1.67^{a}±0.58	1.67^{a}±0.58
CV	27.49	25.56
CD	0.81	0.70

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.3.1.1a. Effect of sowing dates and agrochemicals treatments on the number of cobs of maize at harvest during the spring season 2022

Figure 4.3.1.2b. Effect of sowing dates and agrochemicals treatments on the number of cobs of maize at harvest during the spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.3.2 Cob length (cm): The impact of different sowing dates and agrochemicals on Cob length (cm) at harvest is shown in (Table 4.3.2.1 4.3.2.2 and Figure 4.3.2.1a, 4.3.2.2b). In 2022 and 2023, there was a significant difference in the Cob length (cm) of sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with the control. Thus, the percentage pattern in the Cob length (cm) was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 12.74%; in late sowing, it increased by 9.14% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) increased the percentage by 4.33% when compared to the control (A0). The application of salicylic acid (A2) showed a better result and increased the rate by 23.09% as compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the percentage by 4.33% compared to the control (A0). In the year 2023, it was also found that early sowing (SE) decreased the percentage by 10.23% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate increased by 7.71% compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) increased the percentage by 4.25% when it was compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 22.55% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 7.85% compared to the control (A0). Synchronisation facilitates the timely initiation of genetic and hormonal mechanisms, resulting in consistent and optimal cob production. The suggested timing establishes the foundation for attaining an optimal quantity of cobs per plant, which is a crucial factor in determining the overall growth and productivity of the crop. To address the influence of environmental stress on cob production per plant, a strategic approach is employed to investigate the potential impact of growth regulators. Salicylic acid, well-known for its participation in plant defence mechanisms, can potentially be utilised for regulating reproductive processes in unfavourable environments. This strategic approach becomes especially pertinent for crops that are planted early, as it provides a method to enhance the resilience of plants against the potential adverse impacts of late frosts on the development of cobs. The activation of stress response genes by salicylic acid has been found to enhance the plant's capacity to endure environmental challenges, thereby facilitating a more consistent and optimal yield of cobs per plant. In addition, using sodium nitroprusside, which acts as a donor of nitric oxide, offers an intervention to maximise the number of cobs produced per plant. When sodium nitroprusside is applied carefully and deliberately, it influences vital physiological processes, such as flower bud differentiation, which is essential for developing cobs. This application aids in determining the ideal cob levels, which is particularly advantageous for crops sown late and need to accelerate their reproductive growth despite having a shorter growing season. The intricate utilization of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from the recommended sowing schedule (Siddique et al., 2021; Sharma et al., 2023; Devi et al., 2023; Yati et al., 2002; Wu and Li 2022; Campos et al., 2023; Mohan et al., 2023; Godínez-Mendoza et al., 2023; Yadav et al., 2023; Kumar and Pathak 2019; Kumar et al., 2019; Kotia et al., 2021). The investigation into the impact of environmental stress on crop yield, precisely the number of cobs per plant, provides a holistic comprehension of the complex dynamics involving timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops planted early encounter difficulties due to late frosts that hinder the ideal result of their cobs. On the other hand, crops that are planted late experience the strain of a shortened growing season, which affects their reproductive processes. Establishing optimal conditions for achieving an ideal number of cobs per plant is contingent upon adhering to scientifically derived recommendations regarding sowing timing. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions that can effectively bolster the resilience of crops. These interventions have the potential to impact cob production, as well as shape the overall growth and productivity of the crop. This scientific investigation illuminates the environmental stressors encountered by crops. It offers a framework for strategic interventions to address these challenges and enhance the yield of cobs per plant for optimal crop growth (Godínez-Mendoza et al., 2023; Yadav et al., 2023; Kumar and Pathak 2019; Kumar et al., 2019; Kotia et al., 2021).

Table 4.3.2.1 Effect of treatments on the cob length (cm) of maize at harvest during the spring season 2022 and 2023

Treatments	Cob length (cm)-2022	Cob length (cm)-2023
Sowing Date		
SE -Early sowing	14.79	16.40
S0 -Optimum sowing	16.95	18.27
SL -Late sowing	18.50	19.68
Agrochemical		
A0- Control	15.44	16.67
A1-Sodium nitroprusside (250 µM/L)	16.11	17.38
A2-Salicylic acid (150mg/L)	19.16	20.43
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	16.27	17.98
Alpha at 0.05		
CV (Sowing date and agrochemical)	8.81	9.07
CV (Sowing)	14.88	12.58
CD (Agrochemical)	2.82	2.58
CD (Sowing)	1.46	1.62

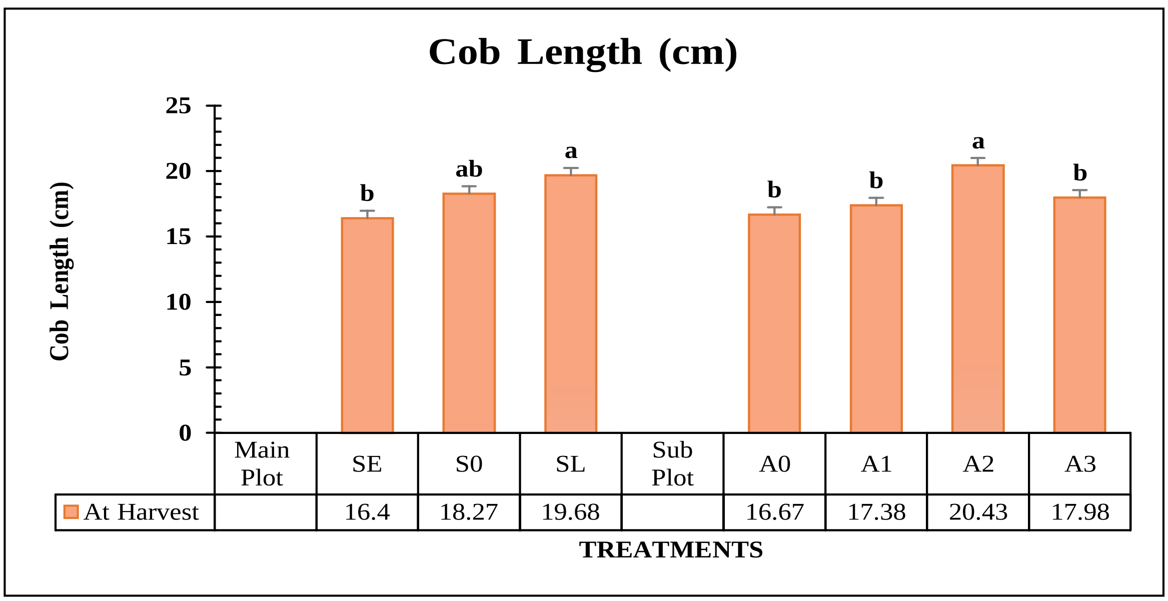
Table 4.3.2.2 The interaction effect of sowing dates and agrochemicals treatments cob length (cm) of maize at harvest during Spring Season 2022 and 2023

Treatments	Cob length (cm)-2022	Cob length (cm)-2023
SEA0	$13.33^{e}\pm1.53$	$14.58^{e}\pm1.53$
SEA1	$14.33^{de}\pm2.25$	$15.67^{de}\pm2.13$
SEA2	$17.50^{abc}\pm1.50$	$18.92^{abc}\pm1.51$
SEA3	$14.00^{de}\pm1.00$	$16.47^{cde}\pm2.33$
S0A0	$16.00^{cde}\pm1.00$	$17.22^{cde}\pm1.03$
S0A1	$16.00^{cde}\pm1.73$	$17.25^{cde}\pm1.73$
S0A2	$19.67^{ab}\pm2.52$	$21.03^{ab}\pm2.33$
S0A3	$16.17^{cde}\pm1.26$	$17.58^{cde}\pm1.13$
SLA0	$17.00^{bcd}\pm1.32$	$18.23^{bcd}\pm1.31$
SLA1	$18.00^{abc}\pm2.00$	$19.25^{abc}\pm2.00$
SLA2	$20.33^{a}\pm1.76$	$21.36^{a}\pm1.74$
SLA3	$18.67^{abc}\pm1.53$	$19.90^{abc}\pm1.55$
CV	8.81	9.07
CD	3.54	3.52

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.3.2.1a. Effect of sowing dates and agrochemicals treatments cob length (cm) of maize at harvest during spring season 2022

Figure 4.3.2.2b. Effect of sowing dates and agrochemicals treatments cob length (cm) of maize at harvest during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.3.3 Number of kernel rows/cob: The impact of different sowing dates and agrochemicals on the Number of kernel rows/cob at harvest is shown in (Table 4.3.3.1 4.3.3.2 and Figure 4.3.3.1a, 4.3.3.2b). In 2022 and 2023, there was a significant difference in the Number of kernel rows/cob sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Number of kernel rows/cob was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 4.50%, and in late sowing, it decreased by 2.25% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) increased the percentage by 3.32% when it was compared to the control (A0). The application of salicylic acid (A2) showed a better result by increasing the rate by 11.14% as compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the rate by 7.34% compared to the control (A0). In 2023, it was also found that early sowing (SE) decreased the percentage by 3.19% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate fell by 1.02% compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) increased the percentage by 3.06% compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 10.64% when compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 7.57% compared to the control (A0). Within the complex domain of crop physiology, assessing the number of kernel rows per cob serves as a prominent and discernible metric, providing pivotal observations regarding the adaptive responses of plants to various environmental stressors. This study examines the intricate relationships between the number of kernel rows per cob in crops that have been sown at inappropriate times, either too early or too late, compared to the recommended planting schedule. Gaining insight into the fluctuations in the quantity of kernel rows is crucial for comprehending the effects of environmental factors, timing of germination, and subsequent growth and reproductive processes. Sowing seeds at an early stage initiates a sequence of environmental stress factors that substantially impact the number of kernel rows observed in developing seedlings (Avinash Sharma et al., 2023;

Sánchez-Castro et al., 2023; Siddique et al., 2018; Kumar et al., 2019; Kumar and Dwivedi 2020). The potential disruption of the delicate balance of reproductive processes crucial for kernel row development becomes evident due to the imminent risk of late spring frosts. The presence of low temperatures hampers vital physiological mechanisms, thereby affecting the differentiation of flower buds and resulting in compromised formation of kernel rows. Within the realm of early-sown crops, the issue of a decreased quantity of kernel rows emerges as a significant matter of concern, which can lead to a decline in crop productivity and hinder the overall growth and development of the plants. On the other hand, sowing crops later than usual introduces a specific array of environmental stress factors that intricately impact the number of kernel rows in the crops. The compressed duration of the growing season places significant demands on plants to accelerate their vegetative and reproductive growth. During this tight period, there is a possibility of a decrease in kernel rows as plants expedite their growth stages and allocate resources towards reproductive processes. Time constraints limit the ability of crops to maximize their number of kernel rows. This highlights the importance of maintaining a precise equilibrium to attain an optimal quantity of kernel rows while considering the impact of diverse environmental stressors that arise from deviations in the suggested timing for sowing. The timing of sowing is a crucial factor in scientific investigations about the number of kernel rows, as it plays a significant role in determining the ideal conditions for crop growth and development. The timing of this phenomenon coincides with advantageous environmental factors such as temperature, soil moisture, and duration of daylight, all of which play a role in facilitating efficient differentiation of kernel rows. Synchronization facilitates the timely initiation of genetic and hormonal mechanisms, promoting consistent and optimal development of kernel rows. The suggested timing establishes the foundation for attaining an optimal quantity of kernel rows, a crucial factor influencing the overall development and productivity of the crop. (Krishna, et al., 2018; Kumar and Dwivedi 2018; Pandey et al., 2018; Pankaj et al., 2012b; Kumar et al., 2018; Yumnam et al., 2018). A systematic approach investigates the potential impact of growth regulators to address the influence of environmental stress on the quantity of kernel rows. Salicylic acid, a well-known compound recognized for its significant role in plant defence mechanisms, has the potential to be utilized in the regulation of reproductive processes during unfavourable environmental circumstances. This strategic approach becomes exceptionally substantial for crops that are planted early, as it provides a method to enhance the resilience of plants against the potential adverse impacts of late frosts on the development of kernel rows. The activation of stress response genes by salicylic acid has been found to enhance the plant's capacity to endure environmental challenges, thereby facilitating a more consistent and optimal number of kernel rows. When s odium nitroprusside is applied carefully and deliberately, it impacts critical physiological processes, such as the differentiation of flower buds, which is essential for developing kernel rows (Hasnain et al., 2023; Mandal et al., 2023; Zhang et al., 2023; Boamah et al., 2023; Omidvari et al., 2023; Geetha et al., 2023; Mahawar et al., 2023; Ain et al., 2023; Abdelsattar et al., 2023; Wu et al., 2023; Li et al., 2023). This application aids in determining the ideal number of kernel rows, which is particularly advantageous for crops that are sown late and need to accelerate their reproductive growth despite having a shorter growing season. The intricate utilization of these growth regulators underscores their capacity to regulate the physiological reactions of crops when confronted with environmental stressors linked to deviations from the recommended sowing schedule. The investigation into the impact of environmental stress on the number of kernel rows in crops provides a holistic comprehension of the complex dynamics involving timing, growth conditions, and vegetative and reproductive maturation. Crops planted early encounter difficulties due to late frosts that hinder the ideal development of kernel rows. On the other hand, crops that are planted late experience the pressure of a shortened growing season, which impacts their reproductive processes. Establishing optimal conditions for achieving an ideal number of kernel rows is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents a strategic means of improving the robustness of crops, impacting the formation of kernel rows and influencing the overall development and productivity of the crop. This scientific investigation illuminates the environmental stressors encountered by crops. It offers a framework for strategic interventions to address these challenges and enhance the number of kernel rows for optimal crop growth.

Table 4.3.3.1 Effect of treatments on the number of kernel rows/cob of maize at harvest during the spring season 2022 and 2023

Treatments	Number of kernel rows/cob - 2022	Number of kernel rows/cob - 2023
Sowing Date		
SE -Early sowing	14.00	15.16
S0 -Optimum sowing	14.66	15.66
SL -Late sowing	14.33	15.50
Agrochemical		
A0- Control	13.55	14.66
A1-Sodium nitroprusside (250 µM/L)	14.00	15.11
A2-Salicylic acid (150mg/L)	15.11	16.22
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	14.66	15.77
Alpha at 0.05		
CV (Sowing date and agrochemical)	5.70	5.43
CV (Sowing)	9.01	9.41
CD (Agrochemical)	1.46	1.64
CD (Sowing)	0.80	0.83

Table 4.3.3.2 The interaction effect of treatments on the number of kernel row/cob of maize at harvest during the spring season of 2022 and 2023

Treatments	Number of kernel rows/cob - 2022	Number of kernel rows/cob - 2023
SEA0	12.00^{c}±0.00	13.33^{c}±0.58
SEA1	15.33^{a} ±1.15	16.67^{a}±1.53
SEA2	14.67^{a} ±1.15	15.67^{b}±1.15
SEA3	14.00^{ab} ±0.00	15.33^{b}±0.58
S0A0	14.67^{a} ±1.15	15.67^{b}±1.15
S0A1	14.00^{ab} ±1.15	15.67^{b}±1.15
S0A2	15.33^{a} ±0.00	16.33^{a}±1.15
S0A3	14.67^{a} ±1.15	15.67^{b}±1.15
SLA0	14.00 ^{ab}±1.15	15.33^{b}±0.58
SLA1	12.67^{bc}±0.00	13.67^{c}±1.15
SLA2	15.33^{a} ±1.15	16.67^{a}±1.53
SLA3	15.33^{a} ±1.15	16.67^{a}±0.58
CV	5.70	5.43
CD	1.88	2.04

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.3.3.1a. Effect of sowing dates and agrochemicals treatments on the number of kernel row/cob of maize at harvest during spring season 2022

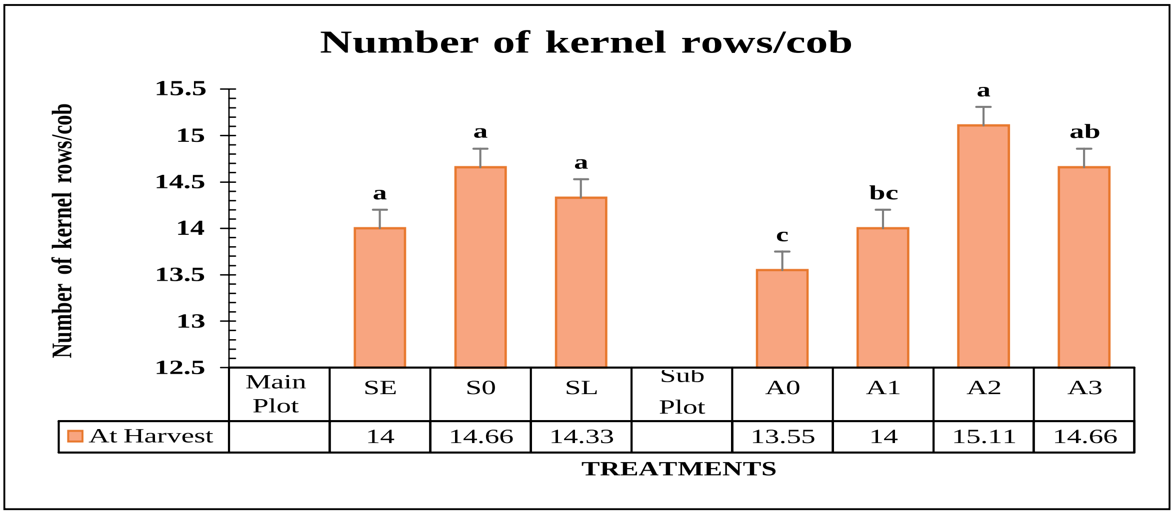
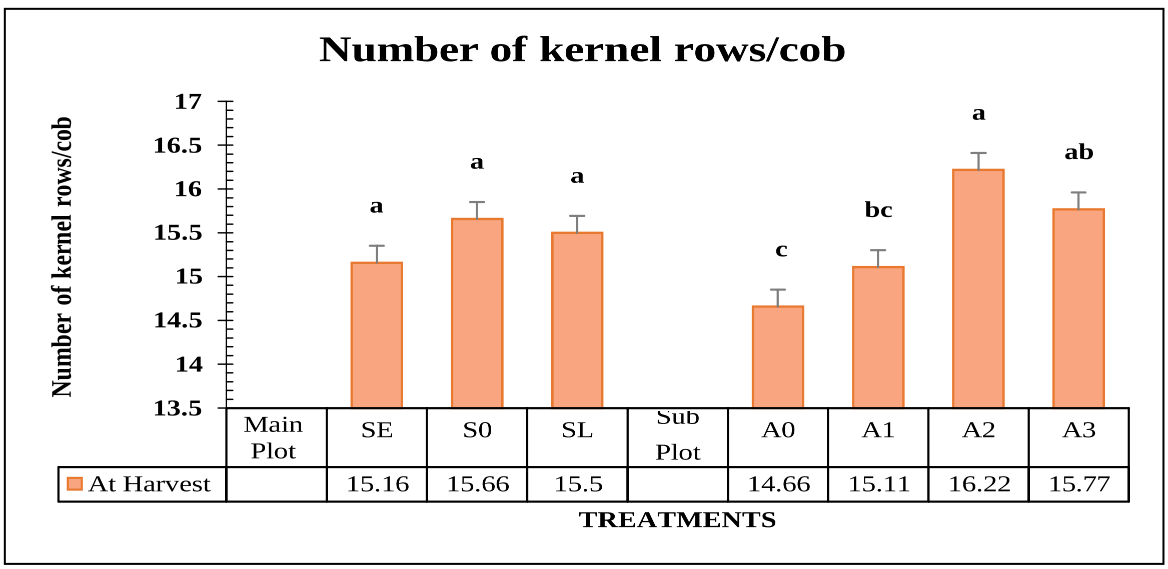


Figure 4.3.3.2b. Effect of sowing dates and agrochemicals treatments on the number of kernel row/cob of maize at harvest during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.3.4 Number of kernel/cobs: The impact of different sowing dates and agrochemicals on the Number of kernels/cobs at harvest is shown in (Table 4.3.4.1 4.3.4.2 and Figure 4.3.4.1a, 4.3.4.2b). In 2022 and 2023, there was a significant difference in the Number of kernels/cobs sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with control. Thus, kernel/cob percentage patterns were observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 23.15%, and in late sowing, it decreased by 0.20% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) reduced the percentage by 6.45% when compared to the control (A0). The application of salicylic acid (A2) showed a better result by increasing the rate by 25.89% compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the rate by 8.18% compared to the control (A0). In the year 2023, it was also found that early sowing (SE) decreased the percentage by 22.54% as compared to the optimum sowing (S0). In the case of late sowing (SL), the rate decreased by 0.10% compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) reduced the rate by 6.25% as compared to the control (A0). The application of salicylic acid showed a better result by increasing the speed by 23.57% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 9.88% compared to the control (A0). The kernel count per cob assessment serves as a discernible metric, providing vital insights into the response of plants to various environmental stressors. This study investigates the intricate dynamics of kernel count per cob in crops subjected to untimely sowing, either through early or late planting, in contrast to the recommended planting schedule. Comprehending the fluctuations in kernel count is crucial for elucidating the influence of environmental factors, timing of germination, and subsequent growth and reproductive processes. Sowing seeds at an early stage initiates a sequence of environmental stress factors that substantially impact the number of kernels in newly sprouting seedlings. The potential disruption of the delicate balance of reproductive processes crucial for kernel development becomes evident due to the imminent threat of late spring frosts. The exposure of plants to cold temperatures has been observed to disrupt essential physiological processes, resulting in adverse effects on flower bud differentiation and compromising the formation of kernels. Within the framework of early-sown crops, the occurrence of a decreased quantity of seeds emerges as a significant issue, which has the potential to lead to a decline in crop yield and hinder the overall growth and development of the plants. On the other hand, sowing crops later than usual introduces a unique array of environmental stress factors that intricately impact the quantity of kernels produced(Yumnam, et al., 2018; Kumar et al., 2018; Pandey et al., 2018; Godínez-Mendoza et al., 2023; Mohan et al., 2023; Campos et al., 2023; Wu and Li 2022; Yati et al., 2002). The compressed duration of the growing season places significant demands on plants to accelerate their vegetative and reproductive growth. In this tight period, there exists the possibility of a decrease in the number of kernels as plants expedite their progression through various growth stages, prioritizing the allocation of resources towards reproductive endeavours. The ability of crops to maximize their kernel count is limited by the time constraints they face. This highlights the intricate equilibrium necessary to attain an optimal kernel count in light of diverse environmental stressors linked to deviations from the prescribed sowing schedule. The timing of sowing is considered a crucial factor in scientific investigations regarding kernel count, as it determines the ideal conditions for crop growth and development. The timing of this phenomenon coincides with advantageous environmental factors, such as optimal temperature, adequate soil moisture, and appropriate duration of daylight, all of which contribute to the efficient differentiation of kernels. Synchronization facilitates the timely initiation of genetic and hormonal mechanisms, resulting in consistent and optimal kernel development. The suggested timing establishes the foundation for attaining an optimal quantity of kernels, a crucial factor influencing the overall development and efficiency of the crop. To address the influence of environmental stress on kernel quantity, a strategic methodology investigates the potential impact of growth regulators. Salicylic acid, which is well-known for its role in plant defence mechanisms, has the potential to be utilized in the regulation of reproductive processes during unfavorable circumstances. This strategic approach is especially significant for crops that are planted early, as it provides a method to enhance the resilience of plants against the potential adverse impacts of late frosts on the development of kernels. Salicylic acid's activation of stress response genes has been found to enhance the plant's capacity to endure environmental challenges, thereby facilitating a more consistent and optimal kernel yield. In addition, the utilization of sodium nitroprusside, which acts as a donor of nitric oxide, offers an intervention aimed at maximizing the quantity of kernels. When sodium nitroprusside is applied carefully and deliberately, it can impact critical physiological processes, such as the differentiation of flower buds, which play a fundamental role in the development of kernels. This application aids in determining the ideal number of seeds, which is especially advantageous for crops planted late and need to accelerate their reproductive growth despite having a shorter growing season. The intricate utilization of these growth regulators demonstrates their capacity to regulate the physiological reactions of crops when confronted with environmental stressors linked to deviations from the recommended sowing schedule. In summary, the investigation into the impact of environmental stress on crop kernel count provides a holistic comprehension of the complex dynamics involving timing, growth conditions, and the processes of vegetative and reproductive development. Crops planted early encounter difficulties due to late frosts that hinder the ideal result of kernels. On the other hand, crops that are planted late experience the strain of a shortened growing season, which affects their reproductive processes. Establishing optimal conditions for achieving an ideal number of kernels is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents tactical interventions aimed at augmenting the resilience of crops, exerting an influence on kernel yield and shaping the overall growth and productivity of the crop. This scientific investigation not only elucidates the environmental stress factors encountered by crops but also offers a framework for strategic interventions to address these challenges and maximize the yield of kernels for optimal crop growth (Pankaj et al., 2012b; Yadav et al., 2023; Kumar et al., 2019; Kumar and Pathak 2019; Kotia et al., 2021). .

Table 4.3.4.1 Effect of treatments on the number of kernels/cobs of maize at harvest during spring season 2022 and 2023

Treatments	Number of kernels/cobs -2022	Number of kernels/cobs -2023
Sowing Date		
SE -Early sowing	368.42	381.25
S0 -Optimum sowing	479.42	492.25
SL -Late sowing	478.42	491.75
Agrochemical		
A0- Control	413.22	426.11
A1-Sodium nitroprusside (250 µM/L)	386.56	399.44
A2-Salicylic acid (150mg/L)	513.33	526.56
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	455.22	468.22
Alpha at 0.05		
CV (Sowing date and agrochemical)	11.03	10.73
CV (Sowing)	12.41	12.34
CD (Agrochemical)	62.17	63.63
CD (Sowing)	48.30	48.36

Table 4.3.4.2 The interaction effect of treatments on the number of kernels/cobs of maize at harvest during the spring season 2022 and 2023

Treatments	**Number of kernels/cobs-2022**	**Number of kernels/cobs-2023**
SEA0	333.33^{d}±55.08	374.00^{d} ±10.15
SEA1	378.00^{cd}±13.11	391.00^{cd} ±14.53
SEA2	406.00^{bcd}±26.23	419.00^{bcd} ±27.62
SEA3	356.33^{d}±17.79	368.67^{d} ±18.01
S0A0	490.67^{ab}±85.54	546.33^{ab} ±10.60
S0A1	401.33^{cd}±49.17	436.33^{cd} ±22.19
S0A2	571.67^{a}±20.21	585.00^{a} ±19.08
S0A3	454.00^{bc}±30.79	482.33^{bc} ±11.15
SLA0	415.67^{bcd}±62.93	495.67^{bcd} ±7.77
SLA1	380.33^{cd}±48.99	377.33^{cd} ±22.72
SLA2	562.33^{a}±75.14	557.67^{a} ±20.65
SLA3	555.33^{a}±17.93	568.67^{a} ±19.35
CV	11.03	10.73
CD	94.63	95.63

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.3.4.1a. Effect of sowing dates and agrochemicals treatments on the number of kernels/cobs of maize at harvest during spring season 2022

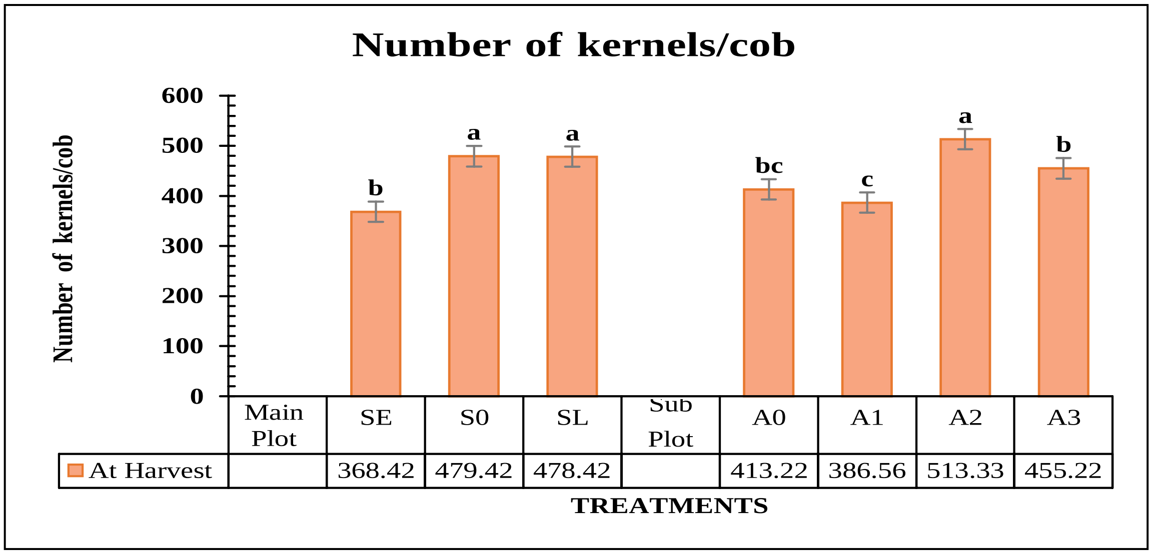
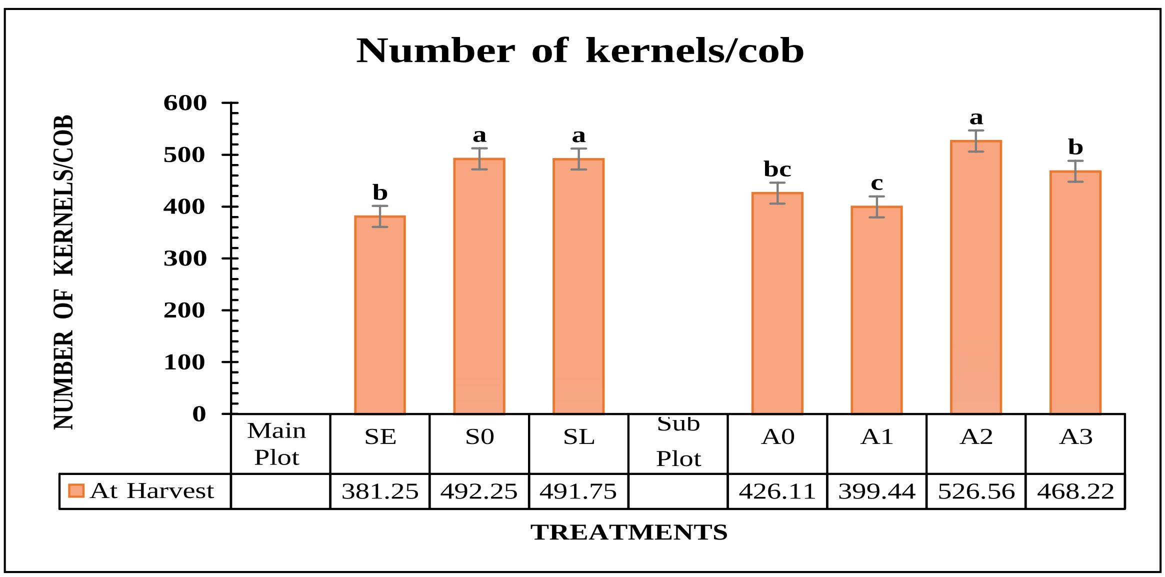


Figure 4.3.4.2b. Effect of sowing dates and agrochemicals treatments on the number of kernels/cobs of maize at harvest during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.3.5 Kernel weight/cob (g): The impact of different sowing dates and agrochemicals on Kernel weight/cob gat harvest is shown in (Table 4.3.5.1 4.3.5.2 and Figure 4.3.5.1a, 4.3.5.2b). In 2022 and 2023, there was a significant difference in the Kernel weight/cob gsowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in the case of different sowing dates. It was estimated by comparing all the standards with the control in agrochemicals. Thus, the percentage pattern in the Kernel weight/cob g was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 10.68%; in late sowing, it decreased by 2.86% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) reduced the percentage by 3.54% when compared to the control (A0). The application of salicylic acid (A2) showed a better result by increasing the rate by 10.22% as compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the rate by 2.01% compared to the control (A0). In the year 2023, it was also found that early sowing (SE) decreased the percentage by 10.19% as compared to the optimum sowing (S0). In the case of late sowing (SL), the rate fell by 2.65 % compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) decreased the percentage by 3.60% compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 9.38% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 2.02% compared to the control (A0). Within the complex realm of crop physiology, the evaluation of kernel weight per cob is crucial as a pivotal indicator, offering essential insights into the adaptive responses of plants to various environmental stressors. This study investigates the intricate dynamics of kernel weight in crops exposed to untimely sowing, either occurring too early or too late, compared to the optimal planting timeframe recommended by experts (Pankaj et al., 2012b; Yadav et al., 2023; Kumar et al., 2019; Kumar and Pathak 2019; Kotia et al., 2021; Dwivedi and Kumar 2011; Kumar and Naik 2020; Pathak et al., 2017; Srivastav et al., 2023; Kumar et al., 2018; Kumar et al., 2011a; Kumar et al., 2018). Gaining insight into the fluctuations in kernel weight is crucial for comprehending the influence of environmental factors, timing of germination, and subsequent growth and reproductive processes. Sowing seeds early introduces environmental stress factors that substantially impact kernels' weight in developing seedlings. The potential disruption of the delicate balance of reproductive processes crucial for kernel development becomes evident due to the imminent threat of late spring frosts. The exposure of plants to cold temperatures has been found to disrupt essential physiological processes, which negatively affects pollination and compromises the formation of kernels. Within the framework of early-sown crops, the issue of decreased kernel weight emerges as a significant matter of concern, as it can lead to a decline in overall crop yield and hinder the overall growth and development of the plants. On the other hand, sowing crops later than usual brings about a specific array of environmental stress factors that intricately impact the weight of kernels. The compressed duration of the growing season places significant demands on plants to accelerate their vegetative and reproductive growth. During this tight period, there is a possibility of a decrease in the weight of kernels as plants accelerate their growth stages and allocate resources towards reproductive activities. The ability of crops to maximize their kernel weight is limited by the time constraints they face. This highlights the importance of maintaining a precise equilibrium to attain an optimal kernel weight amidst diverse environmental stressors linked to deviations from the suggested timing for sowing. The timing of sowing is considered a crucial factor in the scientific investigation of kernel weight, as it determines the ideal conditions for crop growth and development. The synchronization of this timing corresponds to advantageous environmental factors, such as optimal temperature, soil moisture levels, and duration of daylight, all of which contribute to the practical pollination process and the development of kernels. Synchronization facilitates the prompt initiation of genetic and hormonal mechanisms, resulting in consistent and optimal kernel weight. The suggested timing establishes the foundation for attaining an optimal kernel weight, a crucial factor influencing the overall development and productivity of the crop. To alleviate the effects of environmental stress on kernel weight, a strategic approach is employed to investigate the potential influence of growth regulators. Salicylic acid, a well-known compound recognized for its significant role in plant defence mechanisms, has the potential to be utilized in the regulation of reproductive processes during unfavourable environmental circumstances. This strategic approach becomes especially pertinent for crops that are sown early, as it provides a method to enhance the resilience of plants against potential adverse impacts caused by late frosts on the development of kernels. Salicylic acid's activation of stress response genes has enhanced the plant's capacity to endure environmental challenges, which may promote a more uniform and optimal kernel weight. In addition, the utilization of sodium nitroprusside, which acts as a donor of nitric oxide, offers an intervention to enhance the importance of kernels (Pankaj et al., 2012b; Kumar et al., 2018; Siddique et al., 2018; Kumar et al., 2019; Dwivedi et al., 2013; Sharma and Kumar 1999; Siddique and Kumar 2018). When used carefully and deliberately, sodium nitroprusside impacts critical physiological processes, including pollination and kernel development. This application aids in determining the most effective kernel weights, which is particularly advantageous for crops sown late and need to accelerate their reproductive growth within a limited growing season. The intricate utilization of these growth regulators demonstrates their capacity to regulate the physiological reactions of crops when confronted with environmental stressors that arise from deviations in recommended sowing timing. The investigation into the impact of environmental stress on kernel weight in crops provides a thorough comprehension of the complex interaction between timing, growth conditions, and vegetative and reproductive growth. Crops planted early encounter difficulties due to late frosts that hinder the ideal development of kernels. On the other hand, crops that are planted late experience the pressure of a shortened growing season, which affects their reproductive processes. Establishing optimal conditions for achieving an ideal kernel weight is contingent upon adhering to scientifically based recommendations regarding the timing of sowing. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions aimed at augmenting the resilience of crops, thereby impacting kernel yield and influencing the overall growth and productivity of the crop. This scientific investigation illuminates the environmental stress factors encountered by crops and presents a framework for strategic interventions to address these challenges and enhance kernel weight for resilient crop growth.

Table 4.3.5.1 Effect of treatments on kernels weight/cob of maize at harvest during spring season 2022 and 2023

Treatments	Kernels weight/cob 2022	Kernels weight/cob 2023
Sowing Date		
SE -Early sowing	115.23	119.88
S0 -Optimum sowing	129.02	133.49
SL -Late sowing	125.32	129.95
Agrochemical		
A0- Control	120.62	125.33
A1-Sodium nitroprusside (250 µM/L)	116.34	120.81
A2-Salicylic acid (150mg/L)	132.51	137.09
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	123.29	127.87
Alpha at 0.05		
CV (Sowing date and agrochemical)	7.08	6.87
CV (Sowing)	8.09	7.83
CD (Agrochemical)	11.29	11.34
CD (Sowing)	8.63	8.69

Table 4.3.5.2 The interaction effect of treatments on kernels weight/cob of maize at harvest during spring season 2022 and 2023

Treatments	Kernels weight/cob-2022	Kernels weight/cob-2023
SEA0	107.33^{e}±11.21	112.53^{d}±10.66
SEA1	117.93^{cde}±0.98	125.63^{cd}±6.04
SEA2	121.73^{bcde}±3.96	126.20^{bcd}±3.53
SEA3	113.93^{de}±2.14	118.40^{d}±3.18
S0A0	136.73^{ab}±17.32	144.93^{ab}±12.72
S0A1	119.50^{cde}±3.46	123.97^{cd}±4.43
S0A2	135.43^{ab}±2.87	139.90^{ab}±2.43
S0A3	124.43^{abcd}±3.43	128.90^{abcd}±3.53
SLA0	117.80^{cde}±14.92	122.27^{cd}±14.56
SLA1	111.60^{de}±9.38	116.07^{d}±10.01
SLA2	140.37^{a}±10.66	145.17^{a}±10.05
SLA3	131.50^{abc}±1.00	136.30^{abc}±1.22
CV	7.08	6.87
CD	17.03	17.12

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.3.5.1a. Effect of sowing dates and agrochemicals treatments on kernels weight/cob of maize at harvest during spring season 2022

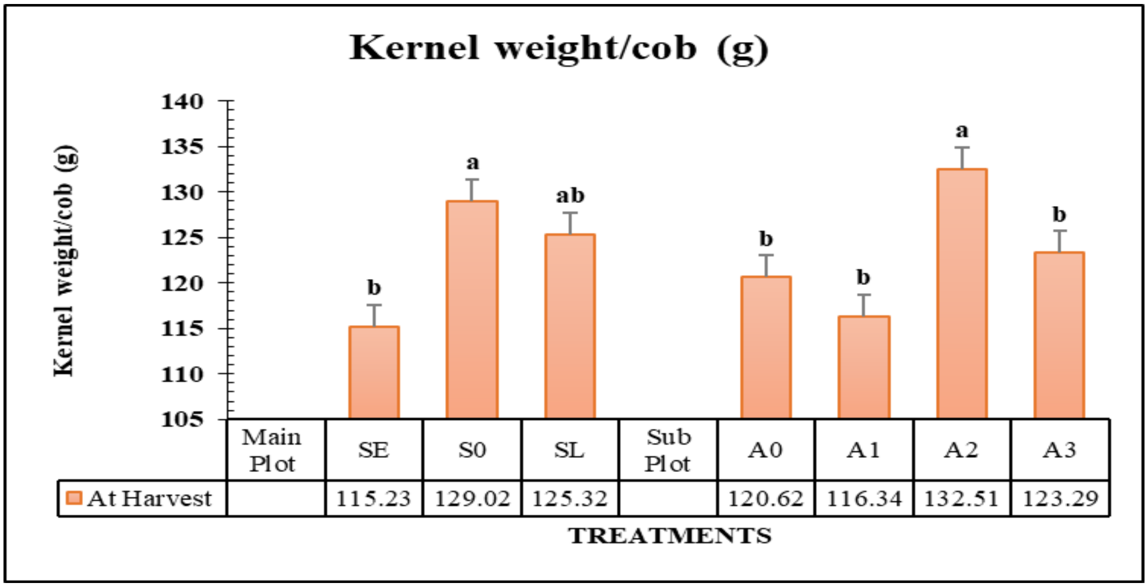
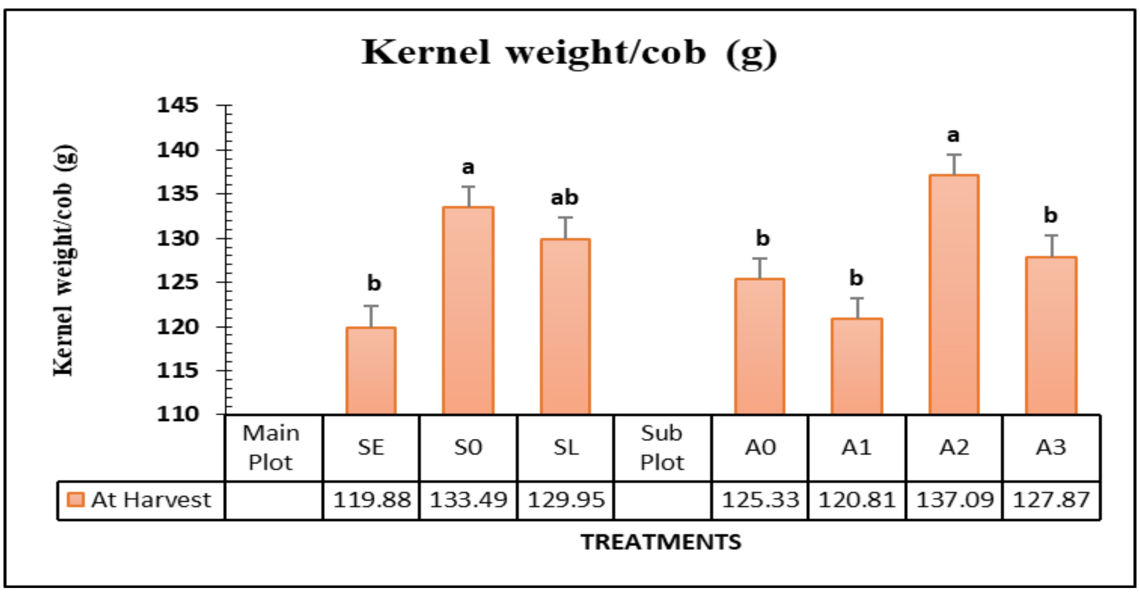


Figure 4.3.5.2b. Effect of sowing dates and agrochemicals treatments on kernels weight/cob of maize at harvest during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.3.6 Diameter of cob (mm): The impact of different sowing dates and agrochemicals on the cob (mm) diameter at harvest is shown in (Table 4.3.6.1 4.3.6.2 4and Figure 4.3.6.1a, 4.3.6.2b). In 2022 and 2023, there was a significant difference in the Diameter of cob (mm)sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. It was estimated by comparing all the standards with the control in agrochemicals. Thus, the percentage pattern in the cob (mm) diameter was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage increased by 0.91%, and in late sowing, it increased by 1.05% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) decreased the percentage by 2.21% compared to the control (A0). When compared to the control (A0), the application of salicylic acid (A2) produced a superior effect, increasing the rate by 4.41%. In comparison to the control (A0), the combination application of sodium nitroprusside as well as salicylic acid (A3) reduced the rate by 1.45%. In 2023, it was also found that early sowing (SE) increased the percentage by 0.97% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate increased by 1.04% compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) decreased the percentage by 1.89% compared to the control (A0). When compared to the control (A0), the application of salicylic acid produced a superior outcome, increasing the rate by 4.25%. Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by decreasing the percentage by 1.39% compared to the control (A0). Within the complex domain of crop physiology, the cob diameter assessment is a significant indicator, providing essential insights into the plant's response to diverse environmental stressors. This study investigates the intricate relationships between cob diameter and the timing of sowing in crops, specifically when sowing occurs either too early or too late instead of following the recommended planting schedule. Comprehending the fluctuations in cob diameter is crucial for elucidating the influence of environmental factors, timing of germination, and subsequent growth and reproductive processes. The practice of sowing seeds at an early stage introduces a range of environmental stress factors that substantially impact the diameter of the cob in newly sprouted seedlings. The potential disruption of the delicate balance of reproductive processes crucial for cob diameter development becomes evident due to the imminent threat of late spring frosts. The exposure to low temperatures has a disruptive effect on essential physiological mechanisms, thereby affecting the process of pollination and resulting in a reduction in cob diameter. Within the realm of early-sown crops, the issue of decreased cob diameter emerges as a significant matter of concern, as it has the potential to lead to a decline in yield and hinder the overall growth and development of the plants. On the other hand, sowing crops later than usual brings about a specific array of environmental stress factors that significantly impact the diameter of cobs. The compressed duration of the growing season places significant demands on plants to accelerate their vegetative and reproductive growth. During this compressed period, the diameter of maize cobs may decrease as plants accelerate their growth stages, directing resources towards reproductive processes. The ability of crops to maximize their cob diameter is limited by the time constraints they face. This highlights the intricate equilibrium necessary to attain an optimal cob diameter amidst diverse environmental stressors linked to deviations from the prescribed sowing schedule. The timing of sowing is considered a crucial element in the scientific investigation of cob diameter, as it determines the ideal conditions for the growth and development of crops. The timing of this phenomenon coincides with advantageous environmental factors, such as optimal temperature, adequate soil moisture, and appropriate duration of daylight. These factors collectively contribute to the effective pollination process and the subsequent development of cob diameter. Synchronization facilitates the prompt initiation of genetic and hormonal mechanisms, promoting consistent and optimal cob diameter. The suggested timing establishes the foundation for attaining an optimal cob diameter, a crucial factor in determining the overall growth and productivity of the crop. A strategic approach is employed to investigate the influence of growth regulators to address the effects of environmental stress on cob diameter. Salicylic acid, a well-known compound recognized for its significant role in plant defence mechanisms, has the potential to be utilized in the regulation of reproductive processes during unfavourable environmental circumstances. This strategic approach is especially significant for crops that are planted early, as it provides a method to enhance the resilience of plants against the potential adverse impacts of late frosts on the development of cob diameter. Salicylic acid's activation of stress response genes has been found to enhance the plant's capacity to endure environmental challenges, potentially leading to a more consistent and optimal cob diameter. In addition, the utilization of sodium nitroprusside, which acts as a donor of nitric oxide, offers an intervention to enhance the diameter of the cob. When sodium nitroprusside is applied carefully and deliberately, it impacts critical physiological processes, including pollination and the development of cob diameter. This application aids in determining the ideal cob diameter, which is particularly advantageous for crops planted late and need to accelerate their reproductive growth despite having a shorter growing season(Zhan et al., 2024; Bhuyan and Deka 2024; Glandorf et al., 2024; Baranski et al., 2024; Gupta et al., 2024). The intricate utilization of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from suggested sowing timing. The investigation into the impact of environmental stress on cob diameter in crops provides a holistic comprehension of the complex interaction between timing, growth conditions, and vegetative and reproductive growth. Crops planted early encounter difficulties due to late frosts that hinder the ideal development of cob diameter. On the other hand, crops that are planted late experience the pressure of a shortened growing season, which affects their reproductive processes. Establishing optimal conditions for achieving an ideal cob diameter is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents tactical interventions for bolstering the resilience of crops, exerting influence on cob diameter production and modulating the overall growth and productivity of the crop. This scientific investigation illuminates the environmental stress factors encountered by crops and offers a framework for deliberate interventions to address these challenges and enhance cob diameter for optimal crop growth.

Table 4.3.6.1 Effect of sowing dates and agrochemicals treatments on the diameter of cob (mm) of maize at harvest during the spring season 2022 and 2023

Treatments	**Diameter of cob (mm) 2022**	**Diameter of cob (mm) 2023**
Sowing Date		
SE -Early sowing	42.98	44.65
S0 -Optimum sowing	42.59	44.22
SL -Late sowing	43.04	44.68
Agrochemical		
A0- Control	42.81	44.41
A1-Sodium nitroprusside (250 µM/L)	41.86	43.57
A2-Salicylic acid (150mg/L)	44.66	46.30
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	42.16	43.79
Alpha at 0.05		
CV (Sowing date and agrochemical)	4.38	4.02
CV (Sowing)	3.23	3.30
CD (Agrochemical)	1.56	1.66
CD (Sowing)	1.85	1.77

Table 4.3.6.2 The interaction effect of treatments on the diameter of cob (mm) of maize at harvest during spring season 2022 and 2023

Treatments	Diameter of cob (mm)-2022	Diameter of cob (mm)-2023
SEA0	42.98^{abcd}±3.01	44.51^{abcd}±3.04
SEA1	42.65^{abcd}±1.98	44.51^{abcd}±2.24
SEA2	45.70^{a}±2.77	47.33^{a}±2.26
SEA3	40.62^{d}±1.95	42.26^{d}±1.52
S0A0	43.34^{abcd}±1.46	44.98^{abcd}±1.86
S0A1	41.67^{cd}±1.06	43.30^{cd}±1.09
S0A2	43.36^{abcd}±1.62	45.00^{abcd}±1.86
S0A3	42.01^{bcd}±0.74	43.64^{bcd}±1.01
SLA0	42.13^{bcd}±0.68	43.76^{bcd}±0.26
SLA1	41.28^{cd}±0.97	42.91^{cd}±0.51
SLA2	44.94^{ab}±1.70	46.57^{ab}±2.18
SLA3	43.85^{abc}±1.66	45.48^{abc}±1.88
CV	4.38	4.02
CD	3.18	3.11

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.3.6.1a. Effect of sowing dates and agrochemicals treatments on the diameter of cob (mm) of maize at harvest during the spring season 2022

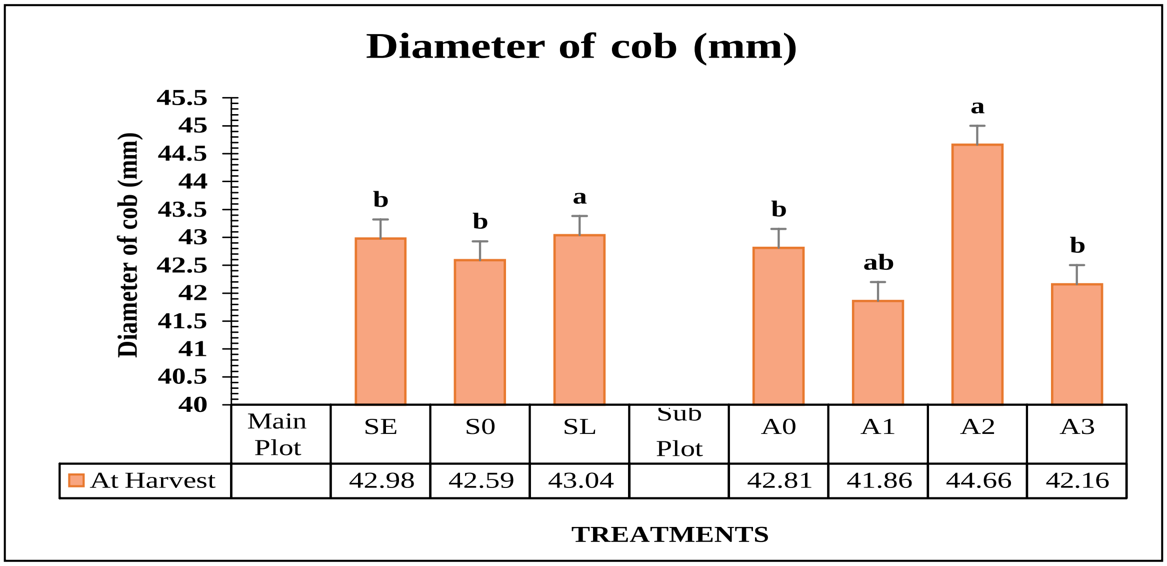
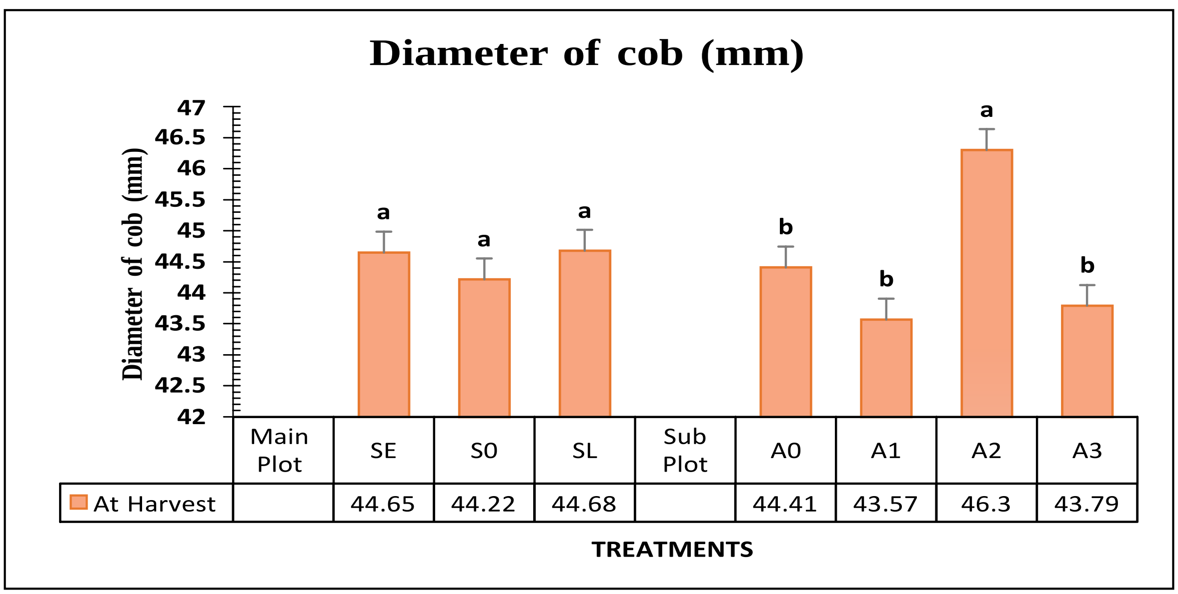


Figure 4.3.6.2b. Effect of sowing dates and agrochemicals treatments on the diameter of cob (mm) of maize at harvest during the spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.3.7 Weight of cob (g): The effect of different sowing dates and agrochemicals on the Weight of cob g at harvest is shown in (Table 4.3.7.1 4.3.7.2 and Figure 4.3.7.1a, 4.3.7.2b). In 2022 and 2023, there was a significant difference in the Weight of cob g sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates and points of agrochemicals; it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Weight of cob g was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 9.83%, and in late sowing, it decreased by 1.99% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) reduced the percentage by 3.62% when it was compared to the control (A0). The application of salicylic acid (A2) showed a better result by increasing the rate by 9.16% when compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the percentage by 2.66% compared to the control (A0). In the year 2023, it was also found that early sowing (SE) decreased the rate by 9.75% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate fell by 1.93 % compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) reduced the percentage by 3.51% when compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 8.71% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 2.95% compared to the control (A0). In the intricate domain of crop physiology, the cob weight assessment is a pivotal indicator, providing crucial insights into how plants respond to diverse environmental stressors. This exploration delves into the nuanced dynamics of cob weight within crops subjected to untimely sowing, either prematurely or belatedly, compared to the recommended planting schedule. Understanding the variations in cob weight is imperative for unravelling the impact of environmental conditions, germination timing, and subsequent vegetative and reproductive development. Early sowing initiates a series of ecological stressors that significantly influence cob weight in emerging seedlings. The looming threat of late spring frosts becomes apparent, potentially disrupting the delicate balance of reproductive processes crucial for cob development. Exposure to cold temperatures interferes with essential physiological functions, impacting pollination and compromising cob formation. In early-sown crops, diminished cob weight becomes a pressing concern, potentially resulting in reduced yield and impairing overall plant growth and development. Conversely, late sowing introduces distinct environmental stressors that influence crop cob weight. The compressed growing season pressures plants to expedite vegetative and reproductive development. Within this condensed timeframe, there is a potential reduction in cob weight as plants hasten through growth stages, allocating resources toward reproductive activities. The capacity of crops to optimize their cob weight faces constraints imposed by the pressing nature of time. This underscores the delicate balance required to achieve an ideal cob weight in the face of varying environmental stressors associated with deviations from the recommended sowing timing. The recommended sowing timing emerges as a critical factor in the scientific exploration of cob weight, establishing optimal crop growth and development conditions. This timing aligns with favourable environmental conditions, including temperature, soil moisture, and daylight duration, all contributing to efficient pollination and cob development (Dwivedi et al., 2011b; Sharma and Kumar 1999; Siddique and Kumar 2018; Siddique et al., 2018). The synchronizations allows for the timely activation of genetic and hormonal processes, leading to uniform and optimal cob weight. The recommended timing sets the stage for achieving an ideal cob weight, a vital determinant of the crop's overall growth and productivity. To mitigate the impact of environmental stress on cob weight, a strategic approach explores the role of growth regulators. Salicylic acid, renowned for its involvement in plant defence responses, can be applied to modulate reproductive processes under adverse conditions. This strategic application becomes particularly relevant for early-sown crops, offering a means to fortify plants against the potential detrimental effects of late frosts on cob development. Salicylic acid's activation of stress response genes enhances the plant's ability to withstand environmental challenges, potentially promoting a more uniform and optimal cob weight. Furthermore, sodium nitroprusside, functioning as a nitric oxide donor, provides an intervention to optimize cob weight. When applied judiciously, sodium nitroprusside influences crucial physiological processes, such as pollination and cob development. This application contributes to establishing optimal cob weights, particularly beneficial for late-sown crops striving to expedite reproductive growth within the constraints of a shortened growing season. The nuanced use of these growth regulators highlights their potential to modulate the physiological responses of crops facing environmental stressors associated with deviations from recommended sowing timing. Exploring environmental stress on cob weight in crops offers a comprehensive understanding of the intricate interplay among timing, growth circumstances, and vegetative and reproductive development. Early-sown crops grapple with the challenges of late frosts impeding optimal cob development, while late-sown counterparts face the stress of a compressed growing season influencing reproductive processes. The recommended sowing timing, grounded in scientific principles, emerges as a pivotal factor in establishing optimal conditions for achieving an ideal cob weight. Integrating growth regulators like salicylic acid and sodium nitroprusside into scientific approaches offers strategic interventions to enhance the resilience of crops, influencing cob production and shaping the overall growth and productivity of the crop. This scientific exploration sheds light on crops' environmental stressors and provides a pathway for strategic interventions to navigate these challenges and optimize cob weight for robust crop development (Costa et al., 2024; Salimi et al., 2024; Mehta et al., 2024; Xiong et al., 2024; Castro-López et al., 2024; Zhang et al., 2024; Misra and Ghosh 2024; Namatsheve et al., 2024; Pandey et al., 2024a; Wang et al., 2024; Chen and Zhu 2024; Ademe et al., 2024; Samy et al., 2024; Akbari et al., 2024; Kaushik et al., 2024; Schasteen 2024).

Table 4.3.7.1 Effect of treatments on cob weight (g) of maize at harvest during spring season 2022 and 2023

Treatments	Cob weight (g)-2022	Cob weight (g)-2023
Sowing Date		
SE -Early sowing	137.83	141.90
S0 -Optimum sowing	152.87	157.23
SL -Late sowing	149.82	154.18
Agrochemical		
A0- Control	143.92	148.09
A1-Sodium nitroprusside (250 µM/L)	138.71	142.88
A2-Salicylic acid (150mg/L)	156.63	161.00
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	148.09	152.46
Alpha at 0.05		
CV (Sowing date and agrochemical)	7.46	7.22
CV (Sowing)	8.46	8.63
CD (Agrochemical)	14.07	14.78
CD (Sowing)	10.85	10.80

Table 4.3.7.2 The interaction effect of treatments on cob weight (g) of maize at harvest during spring season 2022 and 2023

Treatments	Cob weight (g)-2022	Cob weight (g)-2023
SEA0	$107.33^{e}\pm11.21$	$133.27^{e}\pm8.73$
SEA1	$117.93^{cde}\pm0.98$	$144.77^{cde}\pm7.13$
SEA2	$121.73^{bcde}\pm3.96$	$148.93^{bcde}\pm9.10$
SEA3	$113.93^{de}\pm2.14$	$140.63^{de}\pm7.09$
S0A0	$136.73^{ab}\pm17.32$	$167.80^{ab}\pm19.68$
S0A1	$119.50^{cde}\pm3.46$	$147.97^{cde}\pm2.35$
S0A2	$135.43^{abcd}\pm2.87$	$161.87^{abcd}\pm6.18$
S0A3	$124.43^{abcde}\pm3.43$	$151.30^{abcde}\pm6.95$
SLA0	$117.80^{de}\pm14.92$	$143.20^{de}\pm16.67$
SLA1	$111.60^{e}\pm9.38$	$135.90^{e}\pm14.14$
SLA2	$140.37^{a}\pm10.66$	$172.20^{a}\pm14.94$
SLA3	$131.50^{abc}\pm1.00$	$165.43^{abc}\pm5.95$
CV	7.46	7.22
CD	21.33	21.73

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.3.7.1a. Effect of sowing dates and agrochemicals treatments on cob weight (g) of maize at harvest during spring season 2022

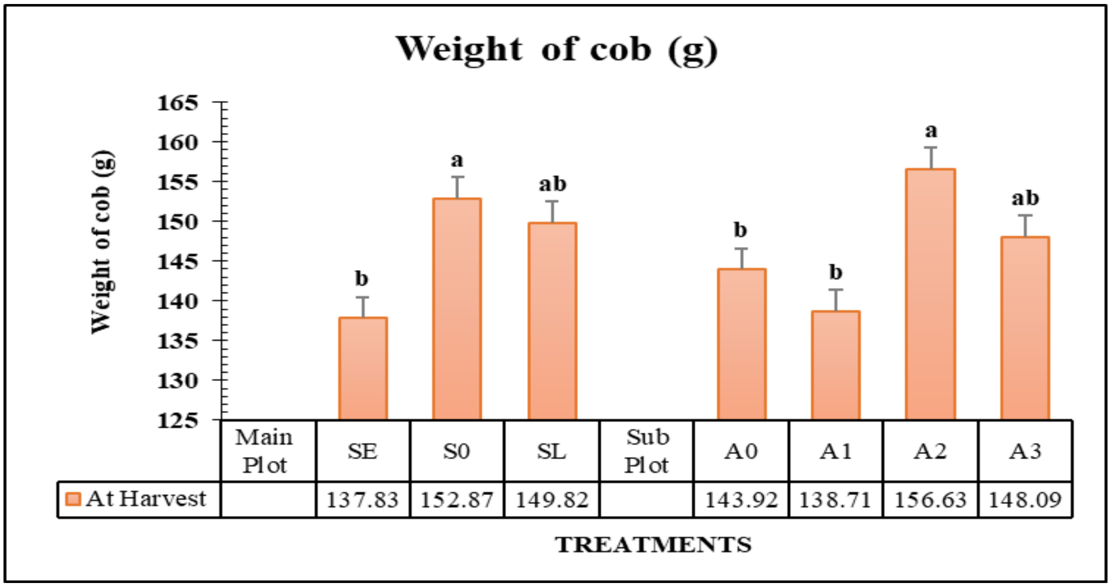
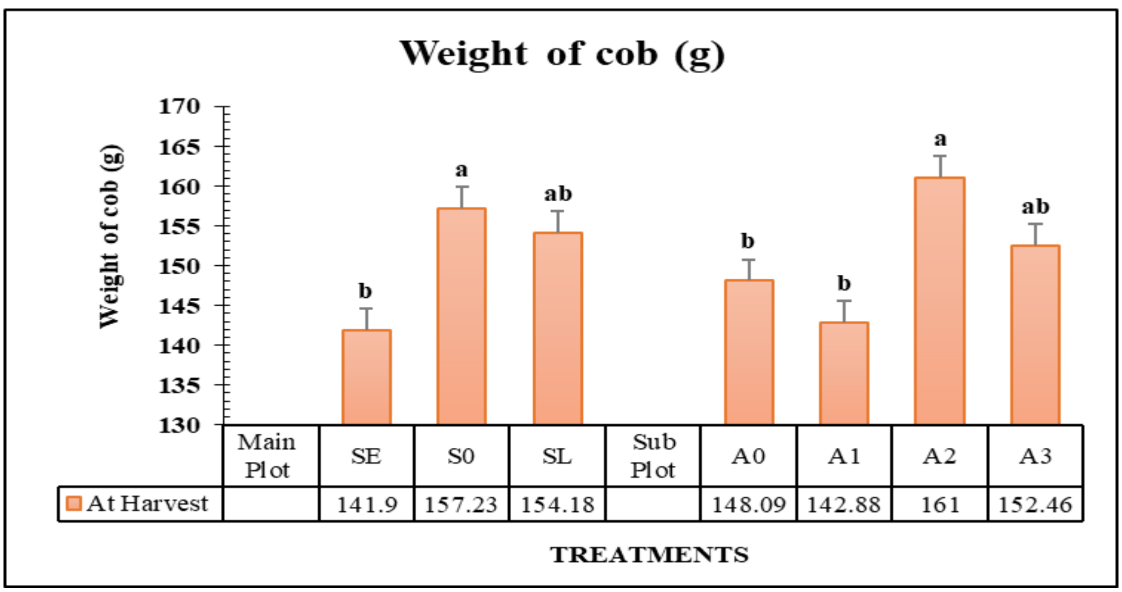


Figure 4.3.7.2b. Effect of sowing dates and agrochemicals treatments on cob weight (g) of maize at harvest during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.3.8 Weight of cob (without grain) (g): The effect of different sowing dates and agrochemicals on the Weight of cob (without grain) g at harvest is shown in (Table 4.3.8.1 4.3.8.2 and Figure 4.3.8.1a, 4.3.8.2b). In 2022 and 2023, there was a significant difference in the Weight of cob (without grain) g sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Weight of cob (without grain) gwas observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 4.05%; in late sowing, it increased by 2.95% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) decreased the percentage by 4.20% when compared to the control (A0). The application of salicylic acid (A2) showed a better result by increasing the rate by 3.27% when it was compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the rate by 5.99% compared to the control (A0). In the year 2023, it was also found that early sowing (SE) decreased the percentage by 3.29% as compared to the optimum sowing (S0). In the case of late sowing (SL), the rate increased by 2.71% compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) decreased the percentage by 3.88% compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 2.50% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 5.29% compared to the control (A0). Within the complex domain of crop physiology, the evaluation of cob (without grain) weight is a significant indicator, offering essential insights into how plants react to diverse environmental stressors. This study investigates the intricate relationships between cobstone weight and the timing of crop sowing, specifically when it occurs either too early or too late, in contrast to the optimal planting schedule. It is crucial to comprehend the fluctuations in cobstone weight to elucidate the influence of environmental factors, the timing of germination, and subsequent growth and reproductive processes. Sowing seeds at an early stage introduces a range of environmental stress factors that notably impact the weight of cobstones in developing seedlings. The potential disruption of the delicate balance of reproductive processes crucial for cobstone development becomes apparent due to the imminent threat of late spring frosts. Cold temperatures have been found to disrupt essential physiological processes, resulting in adverse pollination effects and compromising cobstone formation. Within the framework of early-sown agricultural practices, the issue of decreased cobstone weight emerges as a significant matter of concern, which can lead to a decline in crop yield and hinder the overall growth and development of plants. On the other hand, sowing crops late brings about a unique array of environmental stress factors that significantly impact the weight of cobstones. The compressed duration of the growing season places significant demands on plants to accelerate their vegetative and reproductive growth. In this compressed period, there exists the possibility of a decrease in the weight of cobstones as plants expedite their growth stages, reallocating resources towards reproductive endeavours. Their time constraints limit the ability of crops to maximise the importance of their cobstones. This highlights the intricate equilibrium necessary to attain an optimal cobstone weight amidst diverse environmental stressors linked to deviations from the suggested sowing schedule. The timing of sowing is considered a crucial element in the scientific investigation of cobstone weight, as it determines the most favourable conditions for the growth and development of crops. The synchronisation of this timing corresponds to advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which contribute to the practical process of pollination and the development of maize kernels. Synchronisation facilitates the prompt initiation of genetic and hormonal mechanisms, resulting in consistent and optimal cobstone weight. The suggested timing establishes the foundation for attaining an optimal cobstone weight, a crucial factor in determining the overall growth and productivity of the crop. A strategic methodology is employed to investigate the influence of growth regulators to address the potential consequences of environmental stress on the importance of cobstones. Salicylic acid, well-known for its participation in plant defence mechanisms, has the potential to be utilised for the regulation of reproductive processes in unfavourable circumstances (Costa et al., 2024; Salimi et al., 2024; Mehta et al., 2024; Xiong et al., 2024; Castro-López et al., 2024; Schumacher and Gerhards 2024; Sun et al., 2024; Fan and Critchley 2024; Singh et al., 2024). This strategic approach becomes especially pertinent for crops that are sown early, as it provides a method to enhance the resilience of plants against the potential adverse impacts of late frosts on the development of cobstones. Salicylic acid's activation of stress response genes has been found to enhance the plant's capacity to endure environmental challenges, which may contribute to developing a more consistent and ideal cobstone weight. In addition, using sodium nitroprusside as a donor of nitric oxide presents an intervention aimed at optimising the weight of cobstones. When sodium nitroprusside is applied carefully and deliberately, it can impact essential physiological processes, including pollination and the development of cobstones. This application aids in determining the ideal cobstone weights, which is especially advantageous for crops planted late and need to accelerate their reproductive growth within a limited growing period. The intricate utilization of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from the recommended sowing schedule. In summary, the investigation into the impact of environmental stress on cobstone weight in crops thoroughly comprehends the complex interaction between timing, growth conditions, and vegetative and reproductive development. Crops planted early encounter difficulties due to late frosts that hinder the ideal result of cobstones. Conversely, crops planted late experience the strain of a shortened growing season, which impacts their reproductive processes. Determining the appropriate timing for sowing, based on scientific principles, is crucial in creating favourable conditions to attain the desired weight of cobstones. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents tactical interventions for bolstering the resilience of crops, exerting influence on cobstone formation and modulating the overall growth and productivity of the crop. This scientific investigation illuminates the environmental stress factors encountered by crops. It offers a framework for strategic interventions to address these challenges and enhance cobstone weight for resilient crop growth.

Table 4.3.8.1 Effect of treatments on the weight of cob (without grain) (g) of maize at harvest during the spring season 2022 and 2023

Treatments	Weight of cob (without grain) (g)-2022	Weight of cob (without grain) (g) - 2023
Sowing Date		
SE -Early sowing	22.70	24.95
S0 -Optimum sowing	23.66	25.80
SL -Late sowing	24.36	26.50
Agrochemical		
A0- Control	23.28	25.50
A1-Sodium nitroprusside (250 µM/L)	22.30	24.51
A2-Salicylic acid (150mg/L)	24.01	26.14
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	24.72	26.85
Alpha at 0.05		
CV (Sowing date and agrochemical)	23.15	21.29
CV (Sowing)	24.16	21.52
CD (Agrochemical)	6.45	6.28
CD (Sowing)	5.40	5.42

Table 4.3.8.2 The interaction effect of treatments on the weight of cob (without grain) (g) of maize at harvest during the spring season 2022 and 2023

Treatments	Weight of cob (without grain) (g)-2022	Weight of cob (without grain) (g)-2023
SEA0	22.17^{ab}±4.93	24.53^{ab}±5.34
SEA1	23.33^{ab}±5.13	25.70^{ab}±4.75
SEA2	22.83^{ab}±4.93	24.97^{ab}±4.78
SEA3	22.50^{ab}±6.54	24.63^{ab}±6.94
S0A0	26.83^{ab}±5.13	28.97^{ab}±5.52
S0A1	23.67^{ab}±4.25	25.80^{ab}±4.00
S0A2	21.83^{ab}±2.31	23.97^{ab}±2.14
S0A3	22.33^{ab}±4.04	24.47^{ab}±3.86
SLA0	20.87^{ab}±5.61	23.00^{ab}±5.22
SLA1	19.90^{b}±6.70	22.03^{b}±6.35
SLA2	27.37^{ab}±5.54	29.50^{ab}±5.60
SLA3	29.33^{a}±6.79	31.47^{a}±6.76
CV	23.15	21.29
CD	10.28	10.20

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.3.8.1a. Effect of sowing dates and agrochemicals treatments on the weight of cob (without grain) g of maize at harvest during the spring season 2022

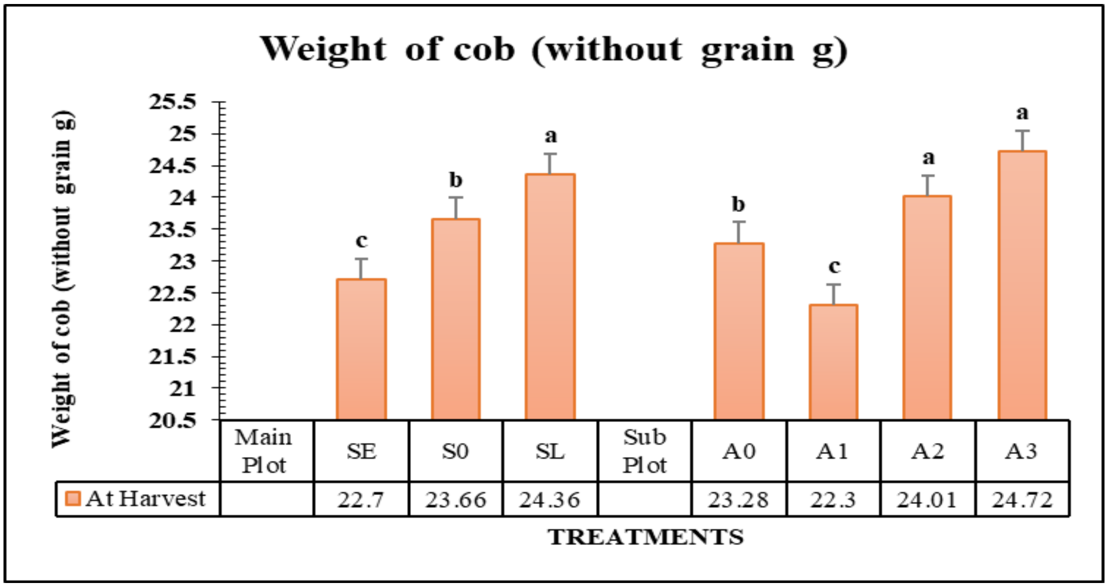
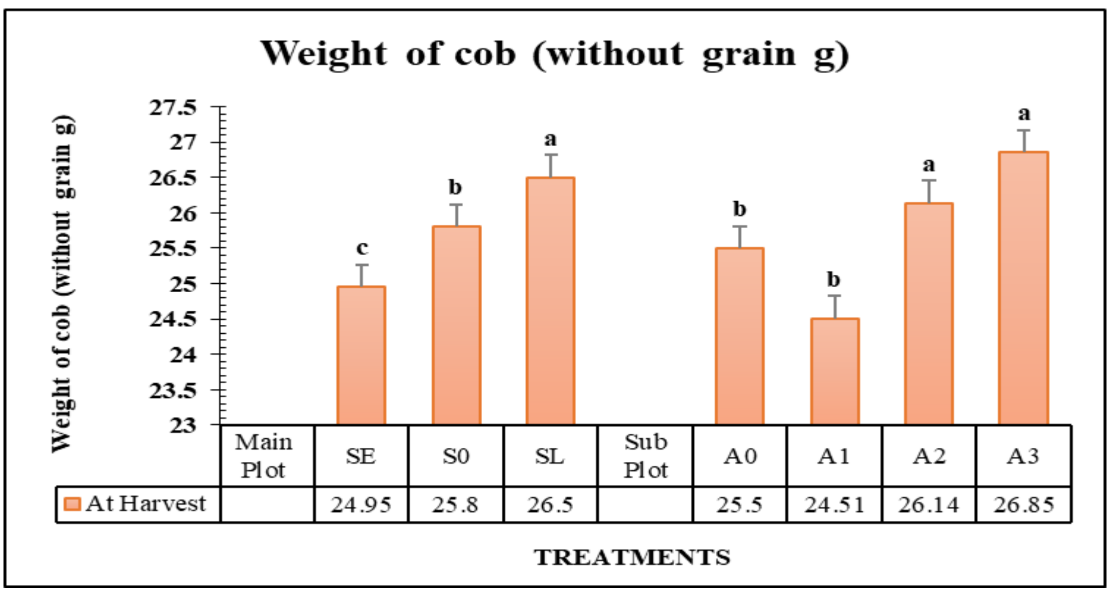


Figure 4.3.8.2b. Effect of sowing dates and agrochemicals treatments on the weight of cob (without grain) g of maize at harvest during the spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.3.9 Stover yield (kg/m^2): The impact of different sowing dates and agrochemicals on the Stover yield (kg/m^2) at harvest is shown in (Table 4.3.9.1 4.3.9.2 Figure 4.3.9.1a, 4.3.9.2bIn 2022 and 2023 there was a significant difference in the Stover yield (kg/m^2) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates, and the point of agrochemicals was calculated by comparing all the standards with the control. Thus, the percentage pattern in the Stover yield (kg/m^2) was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage increased by 14.11%, and in late sowing, it increased by 32.94% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) increased the percentage by 31.16% when compared to the control (A0). The application of salicylic acid (A2) showed a better result by increasing the rate by 34.65% compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the speed by 22.32% compared to the control (A0). In 2023, it was also found that early sowing (SE) increased the percentage by 13.20% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate increased by 27.35% compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) increased the percentage by 24% compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 35% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 23.00% compared to the control (A0). In the complex realm of crop physiology, the assessment of stover yield serves as a pivotal metric, providing essential insights into the response of plants to diverse environmental stressors. This study examines the intricate interplay of stover yield in crops exposed to untimely sowing, either in advance or delayed, in contrast to the prescribed planting timetable. Gaining a comprehensive understanding of the fluctuations in stover yield is crucial to elucidate the effects of environmental factors, timing of germination, and subsequent growth and reproductive processes. Sowing seeds at an early stage introduces a sequence of environmental stress factors that notably impact the yield of plant stalks in newly sprouted seedlings. The potential disruption of the delicate balance of reproductive processes crucial for stover yield development becomes evident due to the imminent threat of late spring frosts. Cold temperatures have a disruptive effect on essential physiological mechanisms, thereby influencing the pollination process and reducing stover yield (Yelin et al., 2024; Pandey et al., 2024d; Ademe et al., 2024; Li et al., 2024; Pandey et al., 2024c; Qi et al., 2024; Yang et al., 2024; Jiang et al., 2024; Ren et al., 2024; Rasmi et al., 2024). Within the framework of early-sown crops, the issue of decreased stover yield emerges as a significant matter of concern, which has the potential to lead to a decline in biomass and hinder the overall growth and development of the plants. On the other hand, sowing crops late brings about a specific array of environmental stressors that significantly impact stover yield. The compressed duration of the growing season places significant stress on plants, compelling them to accelerate both their vegetative and reproductive growth. In this tight period, the possibility of a decrease in stover yield exists as plants expedite their progression through various growth stages, prioritizing the allocation of resources towards reproductive activities. Time constraints limit the ability of crops to maximize their stover yield. Given the diverse environmental stressors arising from deviations in the suggested sowing schedule, this highlights the importance of maintaining a careful equilibrium to attain an optimal stover yield. The timing of sowing is considered a crucial factor in the scientific investigation of stover yield, as it determines the ideal conditions for crop growth and development. The timing of this occurrence coincides with advantageous environmental factors, such as optimal temperature, soil moisture levels, and duration of daylight, all of which contribute to the practical pollination process and stover yield development. Synchronization facilitates the prompt initiation of genetic and hormonal mechanisms, resulting in consistent and optimal stover yield. The recommended timing establishes the foundation for attaining an optimal stover yield, which is a crucial factor in determining the overall growth and productivity of the crop (Mannaa et al., 2024; Zhang et al., 2024; Reetu et al., 2024; Zhao et al., 2024; Yelin et al., 2024; Pandey et al., 2024d; Ademe et al., 2024; Li et al., 2024). A strategic approach is employed to investigate the potential influence of growth regulators to address the adverse effects of environmental stress on stover yield. Salicylic acid, well-known for its role in plant defence mechanisms, can potentially be utilized for regulating reproductive processes in unfavourable environmental circumstances. The strategic implementation of this approach is especially pertinent in the context of crops that are sown early. It provides a method to enhance the resilience of plants against the potential negative impacts of late frosts on the development of stover yield. Salicylic acid's activation of stress response genes has been found to enhance the plant's capacity to endure environmental challenges, thereby facilitating a more consistent and optimal stover yield. In addition, using sodium nitroprusside, which acts as a donor of nitric oxide, offers a potential intervention for enhancing stover yield. When sodium nitroprusside is used carefully and deliberately, it impacts important physiological processes, including pollination and the development of stover yield. This application aids in achieving maximum stover yield, which is particularly advantageous for crops sown late and need to accelerate reproductive growth despite a shorter growing season. The precise utilization of these growth regulators demonstrates their capacity to regulate the physiological reactions of crops when confronted with environmental stressors that arise from deviations in recommended sowing schedules(Zhan et al., 2024; Bhuyan and Deka 2024; Chen and Zhu 2024; Samy et al., 2024; Ademe et al., 2024). The investigation into the impact of environmental stress on stover yield in crops provides a comprehensive comprehension of the complex interaction between timing, growth conditions, and vegetative and reproductive growth. Crops planted early encounter difficulties due to late frosts, which hinder the development of optimal stover yield. On the other hand, crops that are planted late experience the stress of a condensed growing season, which affects their reproductive processes. Determining the appropriate timing for sowing, based on scientific principles, is crucial in creating favourable conditions to maximize stover yield. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies provides strategic interventions to improve crops' resilience. These interventions have the potential to impact the production of crop biomass and influence the overall growth and productivity of the crop. This scientific investigation not only elucidates the environmental stressors encountered by crops but also offers a framework for strategic interventions to address these challenges and enhance stover yield for resilient crop growth.

Table 4.3.9.1 Effect of treatments on the stover yield (kg/m^2) of maize at harvest during spring season 2022 and 2023

Treatments	Stover yield (kg/m^2) -2022	Stover yield (kg/m^2) - 2023
Sowing Date		
SE -Early sowing	0.97	1.2
S0 -Optimum sowing	0.85	1.06
SL -Late sowing	1.13	1.35
Agrochemical		
A0- Control	0.77	1
A1-Sodium nitroprusside (250 µM/L)	1.01	1.24
A2-Salicylic acid (150mg/L)	1.12	1.35
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	1.02	1.25
Alpha at 0.05		
CV (Sowing date and agrochemical)	10.18	9.25
CV (Sowing)	6.63	4.52
CD (Agrochemical)	0.07	0.05
CD (Sowing)	0.09	0.10

Table 4.3.9.2 The interaction effect of treatments on the stover yield (kg/m^2) of maize at harvest during the spring season 2022 and 2023

Treatments	Stover yield (kg/m^2)-2022	Stover yield (kg/m^2)-2023
SEA0	0.66^{fg} ±0.11	0.89^{gh} ±0.09
SEA1	1.07^{c} ±0.07	1.31^{cd} ±0.09
SEA2	1.26^{ab} ±0.06	1.50^{ab} ±0.04
SEA3	0.90^{de} ±0.09	1.11^{ef} ±0.12
S0A0	0.79^{ef} ±0.08	1.01^{fg} ±0.05
S0A1	0.60^{g} ±0.14	0.81^{h} ±0.16
S0A2	0.87^{de} ±0.07	1.09^{ef} ±0.06
S0A3	1.14^{bc} ±0.12	1.36^{bcd} ±0.09
SLA0	0.88^{de} ±0.10	1.10^{ef} ±0.13
SLA1	1.39^{a} ±0.10	1.61^{a} ±0.09
SLA2	1.25^{ab} ±0.09	1.46^{abc} ±0.11
SLA3	1.02^{cd} ±0.07	1.24^{de} ±0.05
CV	10.18	9.25
CD	0.16	0.17

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.3.9.1a. Effect of sowing dates and agrochemicals treatments on the stover yield (kg/m^2) of maize at harvest during spring season 2022

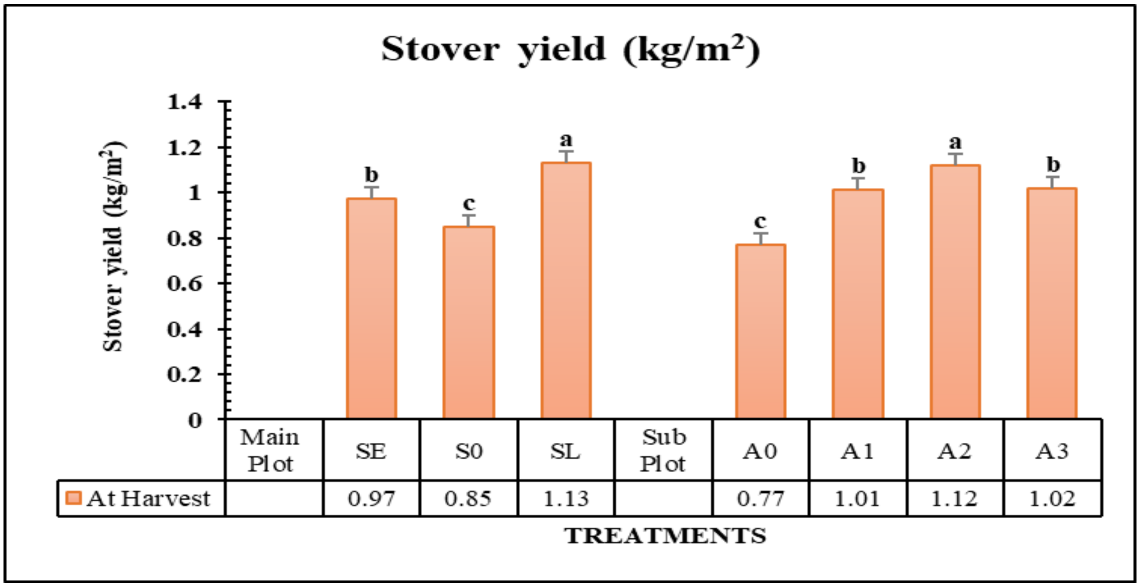
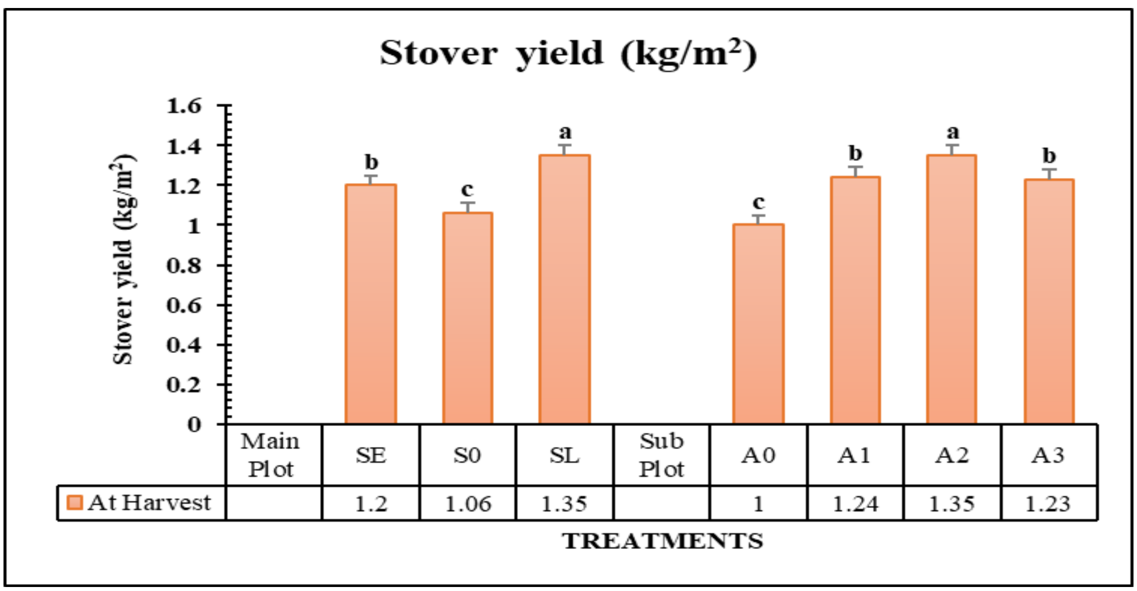


Figure 4.3.9.2b. Effect of sowing dates and agrochemicals treatments on the stover yield (kg/m^2) of maize at harvest during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.3.10 Grain yield (kg/m^2): The impact of different sowing dates and agrochemicals on the Grain yield (kg/m^2) at harvest is shown in (Table 4.3.10.1 4.3.10.2 and Figure 4.3.10.1a, 4.3.10.2b). In 2022 and 2023, there was a significant difference in the Grain yield (kg/m^2) of sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. The point of agrochemicals was calculated by comparing all the standards with control. Thus, the percentage pattern in the Grain yield (kg/m^2) was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 11.86%, and in late sowing, it increased by 1.54% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) increased the percentage by 8.54% when compared to the control (A0). When compared to the control (A0), the application of salicylic acid (A2) had a superior effect, increasing the rate by 8.02%. The combined application of sodium nitroprusside and salicylic acid (A3) increased the rate by 2.46% compared to the control (A0). In the year 2023, it was also found that early sowing (SE) decreased the percentage by 6.74% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate increased by 0.21% compared to the optimum sowing (S0) and in the case of applied agrochemicals, sodium nitroprusside (A1) increased the percentage by 6.75% compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 4.00% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 1.14% compared to the control (A0). The evaluation of grain yield is an essential indicator within the complex dynamics of crop physiology, revealing important information about how plants react to different environmental stressors. This investigation delves into the complex factors affecting grain yield in crops sown before or behind the ideal planting window (Gupta et al., 2024; Stelluti et al., 2024; Maunder et al., 2024; Fan and Critchley 2024; Sun et al., 2024). To determine the role of ecological factors, germination timing, and subsequent vegetative and reproductive development in yield variation, we must first understand these factors. Grain yield in young seedlings is profoundly affected by a cascade of environmental stresses triggered by early sowing. Late spring frosts become a real possibility, which could upset the equilibrium of reproductive processes essential to growing a good harvest crop. Critical physiological processes, such as pollination, are negatively impacted by cold temperatures, resulting in reduced grain yield. In early-sown crops, diminished grain yield becomes a pressing concern, potentially resulting in reduced harvestable crops and impairing overall plant growth and development. On the other hand, crop grain yield is heavily influenced by a new set of environmental stressors introduced due to late sowing. Plants are under intense pressure to speed up their vegetative and reproductive development due to the short growing season. Grain yields may suffer within this compressed timeframe as plants rush through their growth stages and divert resources towards reproduction. Time is a constraining factor in the ability of crops to maximise their grain yield. This highlights the nuanced balancing act necessary to attain an ideal grain yield in the face of variable environmental stressors associated with off-scheduled sowing. In the scientific investigation of grain yield, the recommended sowing timing emerges as a crucial factor in establishing optimal crop growth and development conditions. This timing coincides with optimal climatic conditions such as temperature, soil moisture, and daylight duration, all of which aid in pollination and the growth of grain yields. Timely activation of genetic and hormonal processes that ensure uniform and high grain yield is made possible by synchronisation. The optimal growth and productivity of the crop are heavily dependent on the grain yield, which can be maximised by following the recommended timetable. Exploring the role of growth regulators is a strategic approach to reducing the adverse effects of environmental stress on grain yield. Well-known for its role in plant defence responses, salicylic acid can also control reproduction in challenging environments. This strategic application becomes especially relevant for early-sown crops because of the potential adverse effects of late frosts on grain yield development. Salicylic acid's activation of stress response genes increases the plant's resistance to environmental stresses, which may lead to a higher, more consistent grain yield. As a nitric oxide donor, sodium nitroprusside can also boost grain production (Kotia et al., 2021; Kumar and Naik 2020; Dwivedi and Kumar 2011; Pathak et al., 2017; Srivastav et al., 2023; Pathak et al., 2018; Mandal and Dwivedi 2011a; Kumar et al., 2018; Yumnam et al., 2018; Kumar, et al., 2018; Pankaj et al., 2012b). When used judiciously, sodium nitroprusside influences crucial physiological processes, such as pollination and grain yield development. In particular, late-sown crops working against the clock to speed up reproductive growth within the confines of a shorter growing season will benefit from this application because it helps them establish optimal grain yield. The nuanced use of these growth regulators highlights their potential to modify the physiological responses of crops in the face of environmental stressors associated with deviations from recommended sowing timing. Finally, the study of the effects of environmental stress on crop yield provides a holistic view of the dynamic interplay between time, growth conditions, and vegetative and reproductive development. Late frosts present difficulties for early-sown crops by preventing their optimal development of grain yield, while the stress of a condensed growing season affects the reproductive processes of their later-sown counterparts. The recommended sowing timing is crucial in establishing optimal conditions for achieving an ideal grain yield and is based on sound scientific principles. Strategic interventions incorporating growth regulators like salicylic acid and sodium nitroprusside into science can improve crop resilience by affecting grain yield and moulding the crop's overall growth and productivity. This research identifies the environmental stresses that plants experience and suggests ways to mitigate them through strategic interventions that boost crop productivity.

Table 4.3.10.1 Effect of treatments on the grain yield (kg/m^2) of maize at harvest during spring season 2022 and 2023

Treatments	Grain yield (kg/m^2)-2022	Grain yield (kg/m^2)-2023
Sowing Date		
SE -Early sowing	0.572	0.857
S0 -Optimum sowing	0.649	0.919
SL -Late sowing	0.659	0.921
Agrochemical		
0.908A0- Control	0.597	0.873
A1-Sodium nitroprusside (250 µM/L)	0.605	0.908
A2-Salicylic acid (150mg/L)	0.649	0.932
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	0.613	0.883
Alpha at 0.05		
CV (Sowing date and agrochemical)	8.50	5.82
CV (Sowing)	4.32	9.81
CD (Agrochemical)	0.09	0.10
CD (Sowing)	0.03	0.05

Table 4.3.10.2 The interaction effect of treatments on the grain yield (kg/m^2) of maize at harvest during spring season 2022 and 2023

Treatments	Grain yield (kg/m^2)-2022	Grain yield (kg/m^2)-2023
SEA0	$0.519^{f}\pm0.02$	$0.806^{i}\pm0.06$
SEA1	$0.567^{d}\pm0.06$	$0.880^{f}\pm0.03$
SEA2	$0.641^{c}\pm0.04$	$0.911^{d}\pm0.08$
SEA3	0.564 ± 0.08	$0.834^{g}\pm0.10$
S0A0	$0.717^{a}\pm0.02$	$0.987^{a}\pm0.06$
S0A1	$0.685^{b}\pm0.03$	$0.955^{c}\pm0.09$
S0A2	$0.563^{d}\pm0.06$	$0.833^{g}\pm0.07$
S0A3	$0.632^{c}\pm0.01$	$0.902^{e}\pm0.07$
SLA0	$0.557^{e}\pm0.03$	$0.827^{h}\pm0.03$
SLA1	$0.694^{b}\pm0.04$	$0.964^{b}\pm0.08$
SLA2	$0.743^{a}\pm0.07$	$0.980^{a}\pm0.08$
SLA3	$0.644^{c}\pm0.05$	$0.914^{d}\pm0.10$
CV	8.50	5.82
CD	0.10	0.12

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.3.10.2a. Effect of sowing dates and agrochemicals treatments on the grain yield (kg/m²) of maize at harvest during spring season 2022

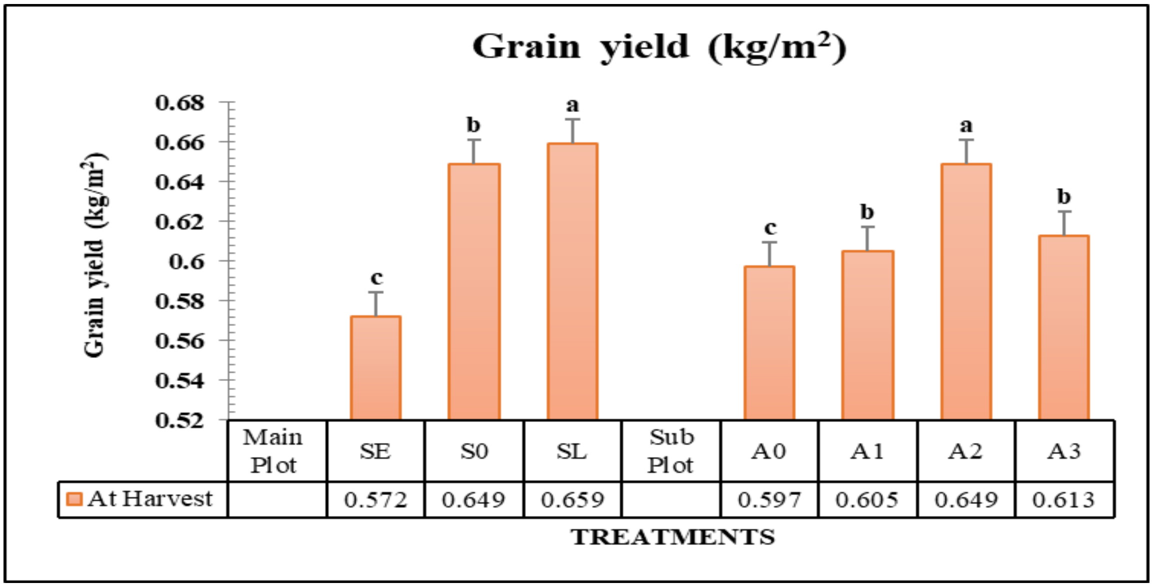
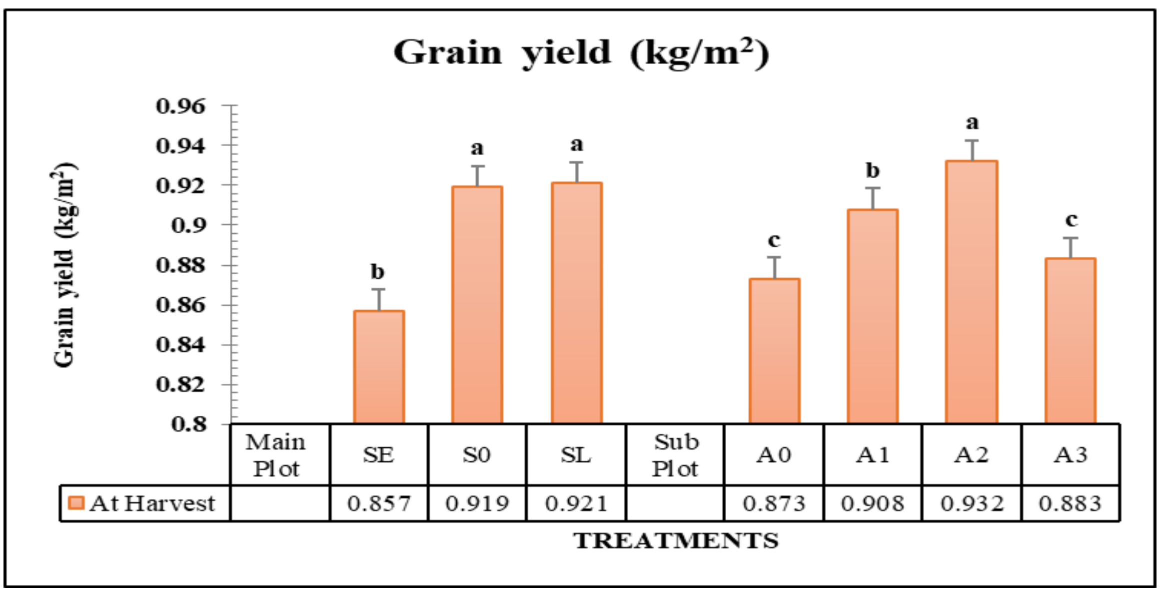


Figure 4.3.10.2b. Effect of sowing dates and agrochemicals treatments on the grain yield (kg/m²) of maize at harvest during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.3.11 Harvesting index (%): The impact of different sowing dates and agrochemicals on the Harvesting index (%) at harvest is shown in (Table 4.3.11.1 4.3.11.2 and Figure 4.3.11.1a, 4.3.11.2b). In 2022 and 2023, there was a significant difference in the Harvesting index (%) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates and points of agrochemicals; it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Harvesting index (%) was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 10.82%, and in late sowing, it decreased by 6.79% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) increased the percentage by 6.10% when compared to the control (A0). The application of salicylic acid (A2) showed a better result by increasing the rate by 7.58% as compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the rate by 0.85% compared to the control (A0). In the year 2023, it was also found that early sowing (SE) decreased the percentage by 9.16% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate fell by 6.97% compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) increased the percentage by 7.83% compared to the control (A0). When compared to the control (A0), the application of salicylic acid produced a superior result, increasing the rate by 9.38%. Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 5.95% compared to the control (A0). The harvest index is an essential metric for determining crop productivity(Sharma et al., 2024; Kumar, 2019; Kotia et al., 2021; Kumar and Naik 2020; Dwivedi and Kumar 2011; Pathak et al., 2017; Srivastav et al., 2023; Kumar and Pathak 2018). It offers insightful information regarding the equilibrium between vegetative and reproductive growth and reflects the efficiency with which plants convert taken-in resources into a yield that can be harvested. This investigation delves into the intricate factors that influence the harvest index within crops that have been sown untimely, either too early or too late, compared to the suggested planting schedule. It is essential to have a solid understanding of the variations in the harvest index to decipher the impact of environmental conditions, the timing of germination, and subsequent vegetative and reproductive development. When you sow seeds too early, you set off a chain reaction of environmental stresses that significantly impact the harvest index of emerging seedlings. The impending danger of late-spring frosts becomes more obvious, and this has the potential to upset the delicate balance of reproductive processes, which is essential for achieving the highest possible harvest index. Cold temperatures disrupt essential physiological processes, which hurts pollination and can reduce the quality of the harvest index (Mandal et al., 2023; Hasnain et al., 2023; Sánchez-Castro et al., 2023; Sharma et al., 2023). In the context of early-sown crops, a decreased harvest index becomes an urgent concern because it can reduce the efficiency with which resources are allocated and impair overall plant growth and development. On the other hand, planting crops later than normal introduces their unique environmental stressors, which profoundly affect the harvest index. The shortened growing season places significant pressure on the plant to hasten the development of its vegetative and reproductive parts. As plants rush through their developmental stages and direct more resources towards their reproductive processes, there is a possibility that the harvest index will decrease within this compressed time frame. The pressing nature of time limits crops' capacity to optimise their harvest index. This places the capacity of crops in jeopardy. This highlights the delicate balance that must be maintained to achieve an ideal harvest index despite the variable environmental stressors associated with deviations from the recommended sowing timing. During the scientific investigation of the harvest index, the optimal conditions for crop growth and development were determined by the recommended sowing timing as a crucial factor. This timing coincides with favourable environmental conditions, including temperature, soil moisture, and duration of daylight, all of which contribute to effective pollination and the development of harvest index. The synchronisation makes it possible to activate genetic and hormonal processes at the right moment, resulting in a consistent and high harvest index. The activation of stress response genes in a plant by salicylic acid results in an increase in the plant's ability to withstand the effects of its environment, which may lead to a harvest index that is more consistent and ideal. in addition, the utilisation of sodium nitroprusside, which acts in the capacity of a nitric oxide donor, constitutes an intervention that maximises the harvest index. Sodium nitroprusside can significantly impact important physiological processes like pollination and the formation of harvest indices when used controlled. This application helps establish an optimal harvest index, which is especially helpful for late-sown crops attempting to accelerate reproductive growth within the constraints of a shorter growing season. The complex application of these growth regulators demonstrates their capacity to modulate the physiological responses of crops when confronted with environmental stressors associated with deviations from the recommended sowing timing. Investigating the effects of environmental stress on the harvest index in crops provides a comprehensive understanding of the complex relationship between the timing of events, the growth circumstances, and vegetative and reproductive development. Early-sown crops have to deal with the difficulties of late frosts, which prevent the development of an optimal harvest index; late-sown crops, on the other hand, have to deal with the stress of a compressed growing season, which influences reproductive processes. The recommended timing of planting, which is based on scientific principles, emerges as a critical component in establishing optimal conditions for achieving an ideal harvest index. Incorporating growth regulators into scientific approaches, such as salicylic acid and sodium nitroprusside, offers strategic interventions to enhance the resilience of crops, influencing harvest index production and moulding the overall growth and productivity of the crop. This scientific investigation sheds light on the environmental stressors that crops face. It provides a pathway for strategic interventions to navigate these challenges and optimise the harvest index for robust crop development. This is because the investigation sheds light on crops' environmental stressors and provides a pathway.

Table 4.3.11.1 Effect of treatments on the harvest index (%) of maize at harvest during spring season 2022 and 2023

Treatments	Harvest index (%) - 2022	Harvest index (%) - 2023
Sowing Date		
SE -Early sowing	38.97	34.10
S0 -Optimum sowing	43.70	37.54
SL -Late sowing	40.73	34.92
Agrochemical		
A0- Control	39.64	33.58
A1-Sodium nitroprusside (250 µM/L)	42.06	36.21
A2-Salicylic acid (150mg/L)	42.83	36.73
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	40.01	35.57
Alpha at 0.05		
CV (Sowing date and agrochemical)	4.12	7.91
CV (Sowing)	8.52	14.20
CD (Agrochemical)	3.97	5.71
CD (Sowing)	1.67	2.78

Table 4.3.11.2 The interaction effect of treatments on the harvest index (%) of maize at harvest during the spring season 2022 and 2023

Treatments	Harvest index (%)-2022	Harvest index (%)-2023
SEA0	34.46^{i}±3.87	31.61^{e}±3.16
SEA1	37.29^{g}±3.57	33.94^{d}±2.00
SEA2	42.44^{d}±0.56	36.71^{c}±1.86
SEA3	41.71^{de}±1.98	34.17^{cd}±2.46
S0A0	48.60^{a}±1.16	36.97^{c}±3.84
S0A1	46.63^{b}±1.23	41.45^{a}±8.75
S0A2	40.91^{e}±2.44	35.35±2.20
S0A3	38.68^{fg}±3.27	36.42^{c}±4.90
SLA0	35.87^{h}±0.54	32.17^{e}±3.75
SLA1	42.26^{d}±1.44	33.24^{d}±2.57
SLA2	45.16^{c}±1.65	38.15^{b}±2.97
SLA3	39.63^{f}±1.57	36.13^{c}±4.00
CV	4.12	7.91
CD	4.66	7.01

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.3.11.1a. Effect of sowing dates and agrochemicals treatments on the harvest index (%) of maize at harvest during spring season 2022

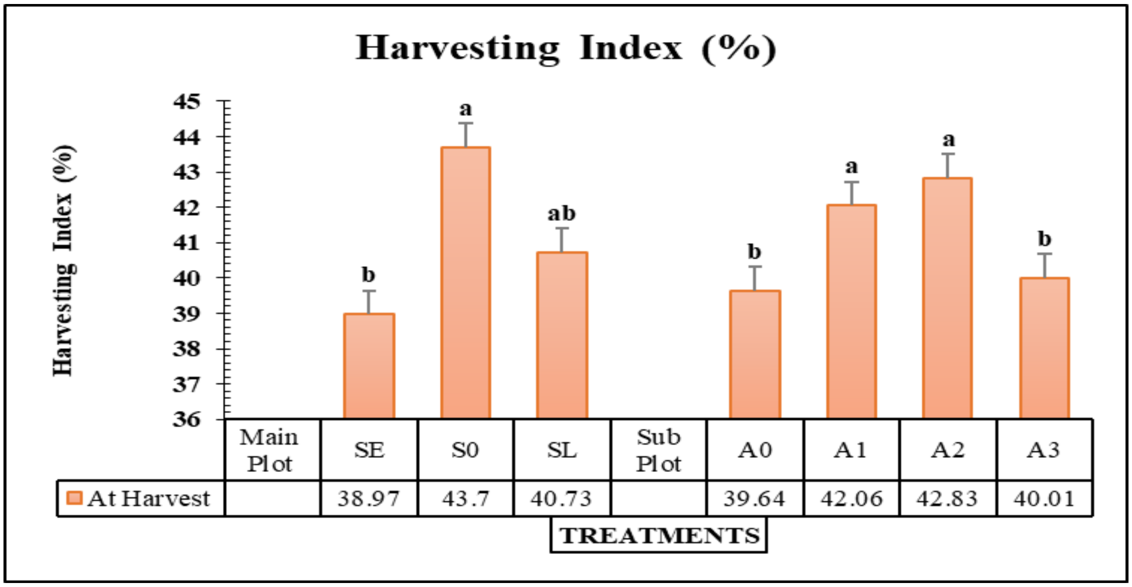
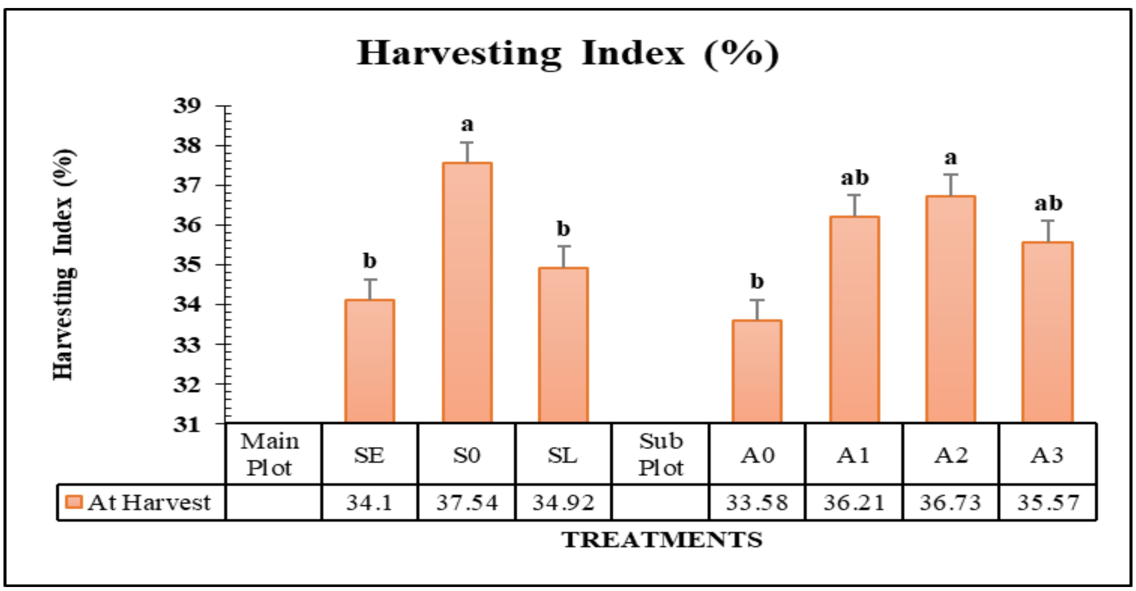


Figure 4.3.11.2b. Effect of sowing dates and agrochemicals treatments on the harvest index (%) of maize at harvest during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.3.12 Test weight (g): The impact of different sowing dates and agrochemicals on the Test weight g at harvest is shown in (Table 4.3.12.1 4.3.12.2 and Figure 4.3.12.1a, 4.3.12.2b). In 2022 and 2023, there was a significant difference in the Test weight g sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates and points of agrochemicals; it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Test weight g was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 4.05%; in late sowing, it increased by 0.36% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) increased the percentage by 6.59% compared to the control (A0). The use of salicylic acid (A2) produced a superior outcome, increasing the rate by 3.96% when compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the rate by 0.89% compared to the control (A0). In the year 2023, it was also found that early sowing (SE) decreased the percentage by 5.96% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate increased by 0.28% compared to the optimum sowing (S0) and in the case of applied agrochemicals, sodium nitroprusside (A1) increased the percentage by 4.57% compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 4.57% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by decreasing the percentage by 0.40% compared to the control (A0). Test weight measurement is essential for evaluating grains and economic worth. It is an indicator of kernel density and the overall compactness of the grain (Paul et al., 2005; Islam et al., 2023; Siddique et al., 2018; Bhatt et al., 2023; Li et al., 2023; Wu et al., 2023; Abdelsattar et al., 2023; Ain et al., 2023; Mahawar et al., 2023). This study examines the intricate variables that impact the yield of crops when they are sown at inappropriate times, either too early or too late, as opposed to the optimal planting timeframe. Comprehending the fluctuations in test weight is crucial for elucidating the influence of environmental factors, timing of germination, and subsequent growth and reproduction. Sowing seeds at an early stage triggers a series of environmental stress factors that substantially impact the test weight of developing seedlings. The potential disruption of the delicate balance of reproductive processes crucial for achieving optimal test weight becomes evident due to the imminent threat of late spring frosts. The exposure to low temperatures has a detrimental effect on essential physiological processes, thereby affecting the development of kernels and resulting in a reduction in test weight. In the context of crops that are sown early, the issue of decreased test weight becomes a significant concern. This could decrease kernel density, negatively impacting the grains' quality and market value. On the other hand, sowing crops later than usual brings about a specific range of environmental stress factors that intricately impact the measure of test weight in crops (Geetha et al., 2023; Boamah et al., 2023; Omidvari et al., 2023; Mahawar et al., 2023; Ain et al., 2023). The compressed duration of the growing season places significant demands on plants to accelerate their vegetative and reproductive growth. During this tight period, there exists the possibility of a decrease in the weight of tests as plants expedite their progress through various growth stages, reallocating resources towards reproductive endeavours. The ability of crops to maximize their test weight is limited by the time constraints they face. This highlights the intricate equilibrium necessary to attain optimal test weight when confronted with diverse environmental stressors linked to deviations from the suggested sowing schedule. The timing of sowing is considered a crucial factor in scientific investigations of test weight, as it determines the ideal conditions for crop growth and development. The timing of this phenomenon corresponds with advantageous environmental factors, such as temperature, soil moisture, and duration of daylight, all of which contribute to kernels' effective filling and test weight development. Synchronisation facilitates the prompt initiation of genetic and hormonal mechanisms, resulting in consistent and optimal test weight. The suggested timing establishes the foundation for attaining an optimal test weight, a critical factor in determining the crop's overall quality and market worth. To address the effects of environmental stress on test weight, a strategic approach involves examining the potential influence of growth regulators. Salicylic acid, well-known for its participation in plant defence mechanisms, can be utilised to regulate kernel development in the presence of unfavourable circumstances. The utilisation of this strategic approach becomes especially significant for crops that are planted early, as it provides a method to enhance the resilience of plants against potential negative impacts caused by late frosts on the development of test weight. Activating stress response genes by salicylic acid enhances the plant's capacity to endure environmental challenges, potentially facilitating a more consistent and optimal test weight. Moreover, the utilization of sodium nitroprusside, which acts as a donor of nitric oxide, offers an intervention to optimize test weight. When sodium nitroprusside is used carefully and deliberately, it impacts important physiological processes, such as the filling of kernels and the development of test weight. This application aids in determining the most favourable test weight, which is especially advantageous for crops sown late and need to accelerate reproductive growth despite a shorter growing season. The intricate utilization of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from the suggested timing for sowing (Abdelsattar et al., 2023; Wu et al., 2023; Li et al., 2023). The investigation into the impact of environmental stress on the weight of crops provides a thorough comprehension of the complex dynamics involving timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops that are sown early encounter difficulties due to late frosts that hinder the development of optimal test weight. On the other hand, crops that are planted late experience the stress of a shortened growing season, affecting kernels' filling and test weight. Establishing optimal conditions for achieving ideal test weight is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions that can effectively bolster the resilience of crops. These interventions can potentially impact the production of test weight and shape the crop's overall quality and market value. This scientific investigation illuminates the environmental stressors encountered by crops and offers a framework for strategic interventions to address these challenges and enhance test weight for resilient crop growth.

Table 4.3.12.1 Effect of on the test weight (g) of maize at harvest during spring season 2022 and 2023

Treatments	Test weight (g)-2022	Test weight (g)-2023
Sowing Date		
SE -Early sowing	23.66	26.33
S0 -Optimum sowing	24.66	28.00
SL -Late sowing	24.75	28.08
Agrochemical		
A0- Control	23.66	26.88
A1-Sodium nitroprusside (250 µM/L)	25.22	28.11
A2-Salicylic acid (150mg/L)	23.66	26.11
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	23.88	26 .77
Alpha at 0.05		
CV (Sowing date and agrochemical)	3.44	4.71
CV (Sowing)	7.85	4.97
CD (Agrochemical)	2.16	1.54
CD (Sowing)	0.83	1.28

Table 4.3.12.2 The interaction effect of treatments on the test weight (g) of maize at harvest during spring season 2022 and 2023

Treatments	Test weight (g)-2022	Test weight (g)-2023
SEA0	22.667^{d} ±1.53	25.00 ^{a}±2.65
SEA1	23.667^{c}±1.53	27.00^{bcde}±3.00
SEA2	25.333^{b}±0.58	28.00^{abc}±0.58
SEA3	23.000^{c}±1.00	25.33^{de}±1.53
S0A0	26.00^{a}±1.53	29.33^{a}±0.58
S0A1	25.66^{b}±0.58	28.66^{abc}±1.15
S0A2	22.66^{d}±2.08	26.66^{cde}±1.15
S0A3	24.33^{c}±1.15	27.33^{abcde}±2.08
SLA0	22.333^{d}±1.15	26.33^{cde}±0.58
SLA1	25.333^{a}±2.00	28.66 ^{abc}±1.53
SLA2	26.000^{a}±1.15	29.66^{a}±1.53
SLA3	24.333^{b}±0.58	27.66^{abcd}±1.53
CV	3.44	4.71
CD	2.47	2.44

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.3.12.1a. Effect of sowing dates and agrochemicals treatments on the test weight g of maize at harvest during spring season 2022

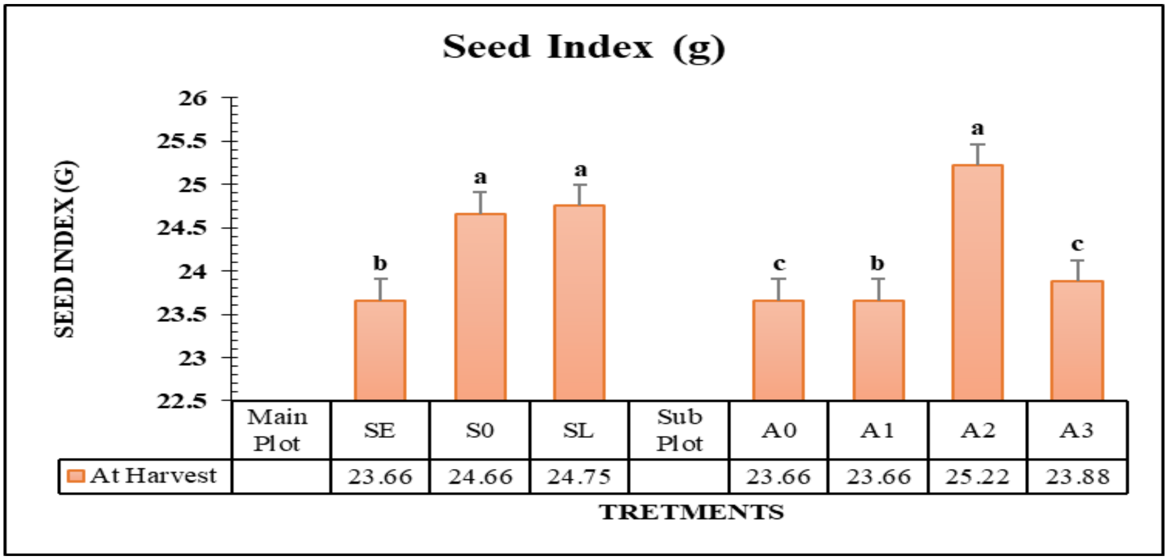
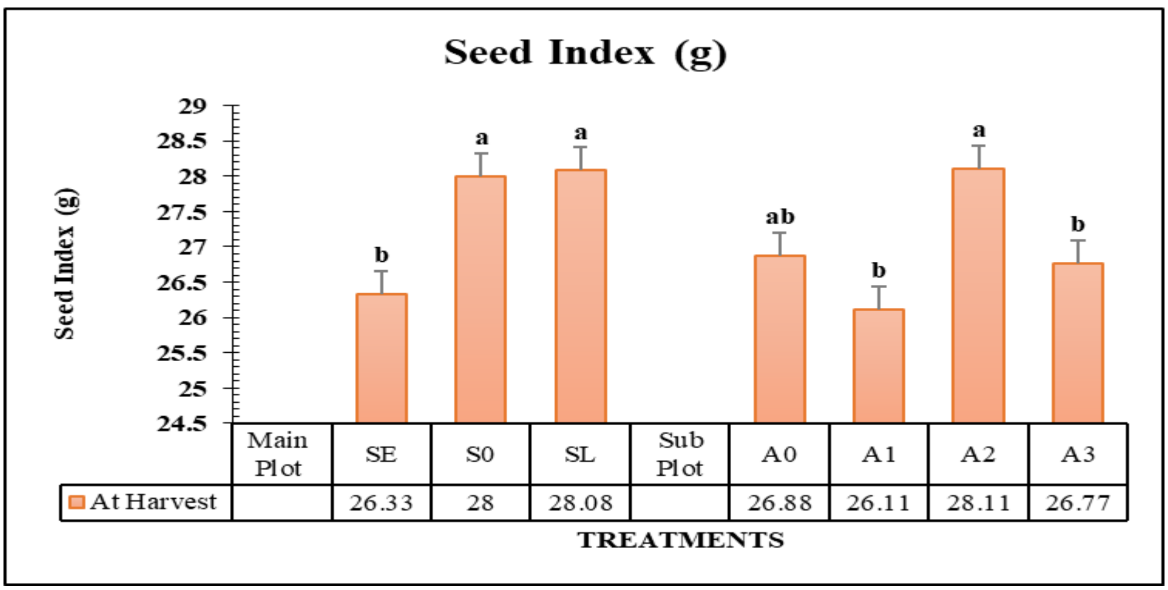


Figure 4.3.12.2b. Effect of sowing dates and agrochemicals treatments on the test weight g of maize at harvest during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.4 Quality parameters of maize seeds and straw

4.4.1 Crude Fiber (%): The impact of different sowing dates and agrochemicals on the Crude Fiber (%) was studied in the PMH-10 variety of Spring maize during 2022 and 2023. Data recorded at 60 and 90 DAS is shown in (Table 4.4.1.1, 4.4.1.2, and Figure 4.4.1.1a, 4.4.1.2b). In 2022 and 2023, there was a significant difference in the percentage of Crude Fiber (%) sowing dates and agrochemicals. The observed ratio was calculated by comparing all the mean with optimum sowing in case of different sowing dates and points of agrochemicals; it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Crude Fiber (%) was observed at 60 and 90 DAS. In 2022, it was found that early sowing (SE) increased the percentage by 79.04%, and late sowing (SL) increased by 2.85% compared to the optimum sowing at 60 DAS. AT 90 DAS, the early sowing decreased the percentage by 1.28%, and late sowing increased the rate by 18.81% compared to the optimum sowing. Among the applied agrochemicals, salicylic acids showed better results by increasing the percentage by 63.08% and 52.75% at 60 and 90 DAS, respectively, compared to control (A0). The application of sodium nitroprusside (A1) also showed a better result by increasing the percentage by 52.29% and 59.34%, followed by A3 by 18.93% and 24.77% at 60 and 90, respectively, as compared to control (A0). In 2023, it was recorded that early sowing (SE) increased the percentage by 80%, and late sowing increased the rate by 2.85% compared to the optimum sowing (S0) at 60 DAS. At 60 DAS, the early sowing (SE) decreased by 1.92%, and late sowing increased the percentage by 18.26% compared to optimum sowing (S0). Salicylic acid outperformed the other agrochemicals tested, increasing the rate of crude fibre by 95.65% and 81.93% at 60 and 90 DAS, respectively, as compared to the control (A0). The application of sodium nitroprusside likewise had a superior outcome, raising the percentage by 51.08% and 56.70%, respectively, at 60 and 90 DAS, as compared to the control (A0). The ability of a plant to produce and store structural carbohydrates is reflected in the amount of crude fibre present in grains; this is an essential component of nutritional composition. This investigation delves into the complex factors that influence the amount of crude fibre contained in crops that were sown either too early or too late compared to the recommended planting schedule. It is necessary to have a solid understanding of the variations in the amount of crude fibre present to decipher the impact that environmental conditions, the timing of germination, and subsequent vegetative and reproductive development have (Chakraborty et al., 2021; Kumar and Dwivedi 2022; Pathak et al., 2018; Kumar et al., 2020). Early sowing starts a chain reaction of ecological stressors that significantly impacts the amount of crude fibre in the emerging seedlings. The impending danger of late-spring frosts becomes more apparent, potentially throwing off the delicate balance of metabolic processes essential for achieving the highest possible crude fibre content. Being subjected to cold temperatures disrupts vital physiological processes, which in turn has an effect on the synthesis of cell walls and leads to a reduction in crude fibre content. In the context of crops that are sown early, a lower natural fibre content becomes an urgent concern because it can reduce structural integrity and impair the overall nutritional quality of the grains. On the other hand, late sowing introduces a new group of environmental stressors, all of which play a significant role in determining the crude fibre content of crops. The shortened growing season places considerable pressure on the plant to hasten the development of both its vegetative and reproductive parts. As plants rush through their developmental stages and direct more resources towards reproductive processes, the amount of crude fibre they contain will decrease within this compressed time frame. Because time is of the essence, there are limits placed on the ability of plants to maximise the amount of crude fibre they contain in their biomass. This highlights the delicate balance that must be maintained to achieve the ideal crude fibre content in the face of the various environmental stressors associated with deviations from the recommended sowing timing. The scientific investigation of crude fibre content reveals that the recommended sowing timing is critical in establishing optimal crop growth and development conditions. This timing coincides with favourable environmental conditions, such as temperature, soil moisture, and the duration of daylight, all of which contribute to efficient metabolic processes that ultimately result in optimal crude fibre synthesis. The synchronisation makes it possible to activate genetic and hormonal methods at precisely the right moment, which eventually results in a crude fibre content that is both consistent and optimal. The optimal amount of crude fibre can be achieved by adhering to the recommended timing, which is also an essential factor in determining the overall nutritional value of the crop.

Table 4.4.1.1 Effect of treatments on crude fibre (%) of maize leaves at 60 and 90 DAS during spring season 2022 and 2023

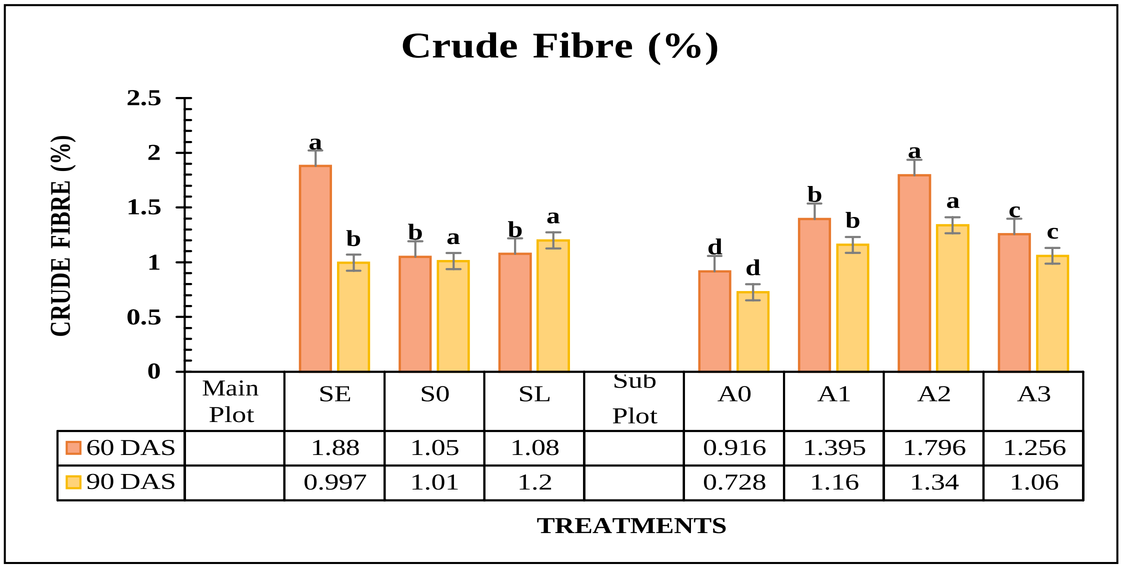
Treatments	Crude fibre (%)-2022		Crude fibre (%)-2023	
Sowing Date				
	60 DAS	**90 DAS**	**60 DAS**	**90 DAS**
SE -Early sowing	1.88	0.997	1.89	1.02
S0 -Optimum sowing	1.05	1.01	1.05	1.04
SL -Late sowing	1.08	1.20	1.08	1.23
Agrochemical				
A0- Control	0.916	0.728	0.920	0.753
A1-Sodium nitroprusside (250 µM/L)	1.395	1.16	1.39	1.18
A2-Salicylic acid (150mg/L)	1.796	1.34	1.80	1.37
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	1.256	1.06	1.26	1.09
Alpha at 0.05				
CV (Sowing date and agrochemical)	7.75	18.72	7.73	18.30
CV (Sowing)	8.48	33.70	8.46	32.93
CD (Agrochemical)	0.12	0.41	0.13	0.43
CD (Sowing)	0.10	0.19	0.11	0.18

Table 4.4.1.2 The interaction effect of treatments on crude fibre of maize leaves (%) at 60 and 90 DAS during spring season 2022 and 2023

Treatments	Crude fibre (%)-2022		Crude fibre (%)-2023	
	60 DAS	**90 DAS**	**60 DAS**	**90 DAS**
SEA0	1.63^{c}±0.04	0.52^{i}±0.13	1.63^{c}±0.04	0.54^{g}±0.13
SEA1	2.03^{b}±0.13	1.44^{b}±0.05	2.04^{b}±0.13	1.46^{bc}±0.05
SEA2	2.09^{ab}±0.02	1.24^{d}±0.23	2.09^{ab}±0.02	1.27^{d}±0.23
SEA3	1.81^{c}±0.06	0.80^{h}±0.41	1.81^{c}±0.06	0.82^{f}±0.41
S0A0	0.27^{h}±0.15	0.77^{h}±0.05	0.27^{h}±0.15	0.79^{f}±0.05
S0A1	0.88^{fg}±0.01	1.15^{f}±0.06	0.88^{fg}±0.01	1.14^{e}±0.00
S0A2	2.23^{a}±0.06	1.17^{e}±0.01	2.24^{a}±0.06	1.19^{e}±0.00
S0A3	0.84^{g}±0.01	1.03^{f}±0.00	0.84^{g}±0.00	1.06^{e}±0.00
SLA0	0.85^{g}±0.11	0.90^{g}±0.01	0.86^{g}±0.11	0.93f±0.01
SLA1	1.27^{d}±0.04	0.93±0.00	1.28^{d}±0.04	0.95^{f}±0.00
SLA2	1.07^{ef}±0.04	1.64^{a}±0.62	1.07^{ef}±0.04	1.66^{a}±0.62
SLA3	1.12^{de}±0.32	1.37^{c}±0.00	1.13^{de}±0.32	1.39^{c}±0.00
CV	7.75	18.72	7.73	18.30
CD	0.19	0.50	0.19	0.50

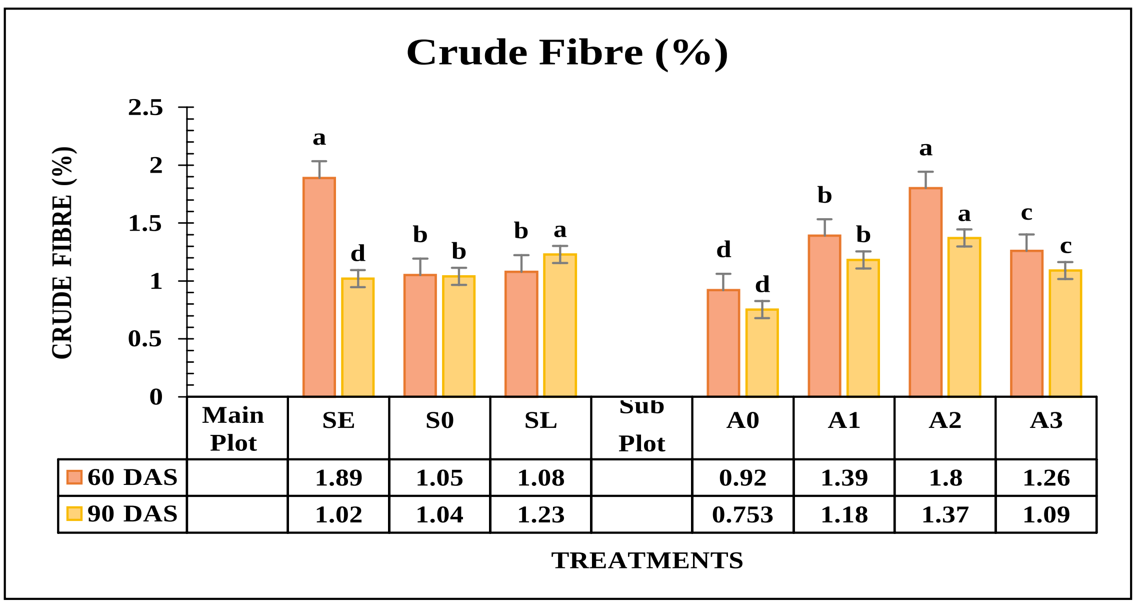
Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.4.1.1a. Effect of sowing dates and agrochemicals treatments on crude fibre (%) of maize leaves at 60 and 90 DAS during spring season 2022



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
60 DAS		1.88	1.05	1.08		0.916	1.395	1.796	1.256
90 DAS		0.997	1.01	1.2		0.728	1.16	1.34	1.06

Figure 4.4.1.2b. Effect of sowing dates and agrochemicals treatments on crude fibre (%) of maize leaves at 60 and 90 DAS during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
60 DAS		1.89	1.05	1.08		0.92	1.39	1.8	1.26
90 DAS		1.02	1.04	1.23		0.753	1.18	1.37	1.09

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.4.2 Crude Fiber (%): The effect of different sowing dates and agrochemicals on Crude Fiber from seed (%) at harvest is shown in (Table 4.4.2.1, 4.4.2.2, and Figure 4.4.2.1a, 4.4.2.2b). In 2022 and 2023, there was a significant difference in the Crude Fiber (%) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. The point of agrochemicals was calculated by comparing all the standards with the control. Thus, the percentage pattern in the Crude Fibre (%) was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage increased by 82.67%, and in late sowing, it increased by 4.17% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) increased the percentage by 49.70% compared to the control (A0). When compared to the control (A0), the administration of salicylic acid (A2) had a superior effect, increasing the rate by 70.00%. In comparison to the control (A0), the combination application of sodium nitroprusside and salicylic acid (A3) enhanced the speed by 19.00%. In 2023, it was also found that early sowing (SE) increased the percentage by 87.04% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate increased by 2.61% compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) increased the percentage by 57.70% compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 10.66% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 40.58% compared to the control (A0). A strategic approach investigates the potential role of growth regulators in mitigating the negative effects of environmental stress on crude fibre content. It is well known that salicylic acid plays a role in plant defence responses; however, it can also be used to modulate metabolic processes when adverse conditions are present. This tactical application becomes especially relevant for early-sown crops, as it provides a means to fortify plants against the potentially detrimental effects of late frosts on developing crude fibre content. The activation of stress response genes in a plant by salicylic acid improves the plant's ability to withstand the effects of its environment, which may lead to the production of a more consistent and optimal amount of crude fibre. In addition, sodium nitroprusside, which performs the role of a nitric oxide donor, constitutes an intervention designed to maximise the amount of crude fibre. Sodium nitroprusside can significantly impact fundamental physiological processes such as the production of crude fibre and metabolic activity when used appropriately. This application helps establish an optimal oil fibre content, which is especially helpful for late-sown crops attempting to accelerate reproductive growth despite the constraints of a shorter growing season. The complex application of these growth regulators demonstrates their capacity to modulate the physiological responses of crops when confronted with environmental stressors associated with deviations from the recommended sowing timing (Pramanik et al., 2023; Sharma et al., 2023; Sánchez-Castro et al., 2023; Hasnain et al., 2023; Mandal et al., 2023; Zhang et al., 2023; Geetha et al., 2023; Boamah et al., 2023; Omidvari et al., 2023; Mahawar et al., 2023; Ain et al., 2023; Chakraborty et al., 2021; Reddy and Dwivedi 2022; Pathak, et al., 2018; Kumar et al., 2020). In conclusion, the investigation of the effects of environmental stress on the crude fibre content of plants provides a comprehensive understanding of the complex relationship between the timing of events, the growth circumstances, and the development of the vegetative and reproductive components of the plant. Early-sown crops have to deal with the difficulty of late frosts, which prevents them from developing their optimal crude fibre content. In contrast, their late-sown counterparts must deal with the stress of a compressed growing season, which affects metabolic processes and natural fibre content. Based on scientific principles, the recommended sowing timing emerges as a pivotal factor in establishing optimal conditions for achieving ideal oil fibre content. This is because the recommended sowing timing comes first in establishing optimal conditions. Incorporating growth regulators into scientific approaches, such as salicylic acid and sodium nitroprusside, offers strategic interventions to enhance the resilience of crops, influencing the production of crude fibre content and shaping the overall nutritional quality of the produce. This scientific investigation sheds light on the environmental stressors that crops face. It provides a pathway for strategic interventions to navigate these challenges and optimise crude fibre content for robust crop development. The investigation sheds light on crops' environmental stressors and provides a pathway.

Table 4.4.2.1 Effect of sowing dates and agrochemicals treatments on crude fibre of maize seeds (%) at harvest during spring season 2022 and 2023

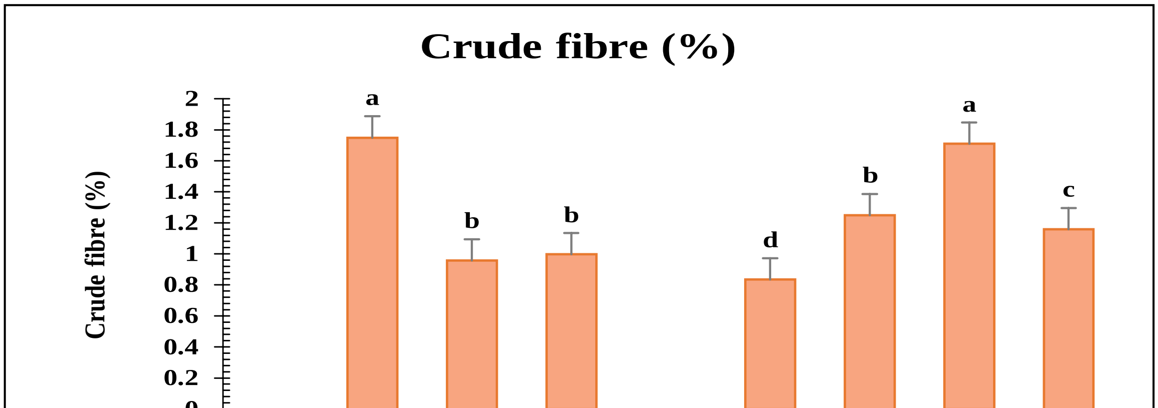
Treatments	Crude fibre (%)-2022	Crude fibre (%)-2023
Sowing Date		
SE -Early sowing	1.75	1.79
S0 -Optimum sowing	0.958	0.957
SL -Late sowing	0.998	0.982
Agrochemical		
A0- Control	0.835	0.818
A1-Sodium nitroprusside (250 µM/L)	1.25	1.29
A2-Salicylic acid (150mg/L)	1.71	1.69
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	1.16	1.15
Alpha at 0.05		
CV (Sowing date and agrochemical)	7.98	8.36
CV (Sowing)	8.59	9.15
CD (Agrochemical)	0.02	0.12
CD (Sowing)	0.03	0.10

Table 4.2.2.2 The interaction effect of treatments on crude fibre of maize seeds (%) at harvest during the spring season of 2022 and 2023

Treatments	Crude fibre (%)-2022	Crude fibre (%)-2023
SEA0	1.43^{c}±0.04	1.53^{c}±0.04
SEA1	1.83^{b}±0.13	1.94^{b}±0.13
SEA2	1.89^{ab}±0.02	1.99^{ab}±0.02
SEA3	1.61^{c}±0.06	1.71^{c}±0.06
S0A0	0.07^{h}±0.15	0.17^{h}±0.15
S0A1	0.68^{fg}±0.01	$0.78f^{g}$±0.01
S0A2	2.03^{a}±0.06	2.14^{a}±0.06
S0A3	0.64^{g}±0.00	0.74^{g}±0.00
SLA0	0.65^{g}±0.11	0.76^{g}±0.11
SLA1	1.07^{d}±0.04	1.18^{d}±0.04
SLA2	0.87^{ef}±0.04	0.97^{ef}±0.04
SLA3	0.92^{de}±0.32	1.03^{de}±0.32
CV	7.98	8.36
CD	0.06	0.17

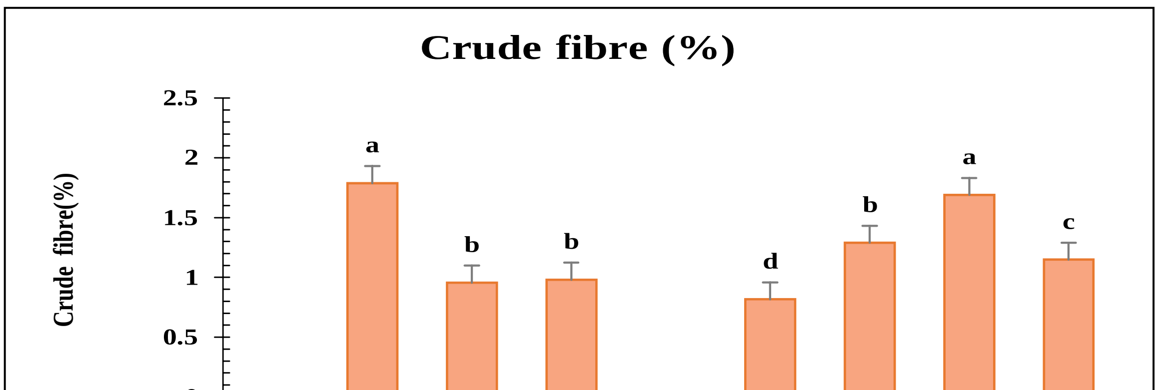
Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.4.2.1a. Effect of sowing dates and agrochemicals treatments on crude fibre of maize seeds (%) at harvest during spring season 2022



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
At harvest		1.75	0.958	0.998		0.835	1.25	1.71	1.16

Figure 4.4.2.2b. Effect of sowing dates and agrochemicals treatments on crude fibre of maize seeds (%) at harvest during spring season 2023



	Main Plot	SE	S0	SL	Sub Plot	A0	A1	A2	A3
At harvest		1.79	0.957	0.982		0.818	1.29	1.69	1.15

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.4.3 Total Soluble Sugar (microgram/ml): The impact of different sowing dates and agrochemicals on Total Soluble Sugar (microgram/ml) from seed at harvest is shown in (Table 4.4.3.1, 4.4.3.2, and Figure 4.4.3.1a, 4.4.3.2b). In 2022 and 2023, there was a significant difference in the Total Soluble Sugar (microgram/ml) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with the control. Thus, the percentage pattern in the Total Soluble Sugar (microgram/ml) was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 83.72%, and in late sowing, it increased by 7.73% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) increased the percentage by 13.37% compared to the control (A0). The application of salicylic acid (A2) showed a better result by increasing the rate by 4.68% compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the rate by 1.13% compared to the control (A0). In 2023, it was also found that early sowing (SE) decreased the percentage by 83.48% compared to the optimum sowing (S0). In the case of late sowing (SL), the percentage increased by 7.71% compared to the optimum sowing (S0) and in the case of applied agrochemicals, sodium nitroprusside (A1) increased the rate by 13.31% compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 5.28% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 1.21% compared to the control (A0). Within the complex domain of crop physiology, the measurement of total sugar content emerges as a pivotal parameter, offering valuable insights into the plant's reaction to various environmental stressors. This scientific investigation examines the intricate dynamics of total sugars in crops exposed to untimely sowing, either in advance or delayed, compared to the prescribed planting timetable. Comprehending the scientific complexities associated with the overall sugar content is imperative to elucidate the intricate relationship between environmental factors, timing of germination, and subsequent growth and reproductive processes (Porter et al., 2024; X. Zhao et al., 2024; Reetu et al., 2024; M. Zhang et al., 2024; Mannaa et al., 2024; Baruah et al., 2024; Kozeko et al., 2024; Bhuyan and Deka 2024; Devos, Oberkofler, and Glandorf

2024; Zhan et al., 2024; Pandey et al., 2024b; Zeb et al., 2024; Fernández-Ortega, Álvaro-Fuentes, and Cantero-Martínez 2024; Mehmood et al., 2024). When seeds are sown before the optimal time, the resulting seedlings are exposed to various environmental stressors that substantially affect the overall sugar content. Late spring frosts present a significant risk, which can potentially hinder the process of optimal sugar synthesis. From a scientific perspective, it has been observed that exposure to cold temperatures can have a disruptive effect on crucial physiological processes. This disruption affects the metabolic pathways responsible for sugar production, impacting total sugars' overall quantity and efficiency. The repercussions of cold stress are evident in the diminished and irregular total sugar levels observed in crops that are sown early, affecting their overall photosynthetic efficiency and subsequent growth. On the other hand, delayed sowing of crops introduces specific environmental stress factors that impact the overall sugar content. The compressed duration of the growing season exerts considerable pressure on plants to accelerate their vegetative and reproductive growth. From a scientific standpoint, the shortened duration could decrease overall sugar content as plants expedite their growth stages to allocate resources towards reproductive processes. Tangible limitations imposed by time constraints hinder the ability of crops to maximize their general sugar content. The scientific complexities of this process highlight the need for a careful equilibrium to attain an optimal total sugar content amidst diverse environmental stressors linked to departure from suggested sowing schedules(Kumar et al., 2018; Pankaj et al., 2012b; Kumar and Dwivedi 2018; Kumar et al., 2018; Kumar et al., 2019; Cheng Song et al., 2024). The timing of sowing is considered a crucial element in scientific research on total sugar content, as it determines the ideal conditions for crop growth and development. The temporal occurrence coincides with advantageous ecological circumstances, encompassing temperature, soil moisture, and daylight duration, collectively contributing to sugar's practical synthesis. From a scientific perspective, this synchronizations facilitates the timely activation of genetic and hormonal processes, ultimately attaining uniform and optimal total sugar content. The suggested timing establishes the foundation for attaining an optimal photosynthetic equilibrium, a crucial factor in determining the crop's overall photosynthetic efficiency and potential yield. To address the effects of environmental stress on the general sugar content, a scientific investigation is undertaken to examine the influence of growth regulators. Salicylic acid, renowned for its participation in plant defence mechanisms, can be strategically administered to regulate sugar synthesis during unfavourable circumstances. From a scientific perspective, activating stress response genes by salicylic acid can improve a plant's capacity to endure environmental challenges, which may result in a more consistent and optimal total sugar content. This strategic approach is especially pertinent for crops that are planted early, as it provides a scientific method to enhance the resilience of plants against the potential negative impacts of late frosts on the process of sugar synthesis. In addition, using sodium nitroprusside as a nitric oxide donor offers a scientific intervention to optimize the overall sugar content. When used carefully and deliberately, sodium nitroprusside impacts vital physiological processes, including cell division and elongation, essential for sugar production. From a scientific perspective, this application plays a role in determining the ideal amount of total sugar content. It is particularly advantageous for crops planted late in the season and needs to promote both vegetative and reproductive growth despite the limitations of a shorter growing period. The intricate utilization of these growth regulators demonstrates their capacity to regulate the physiological reactions of crops when confronted with environmental stressors that arise from deviations in recommended sowing timing. The scientific investigation of the impact of environmental stress on the overall sugar content in crops provides a comprehensive comprehension of the complex interactions between timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops planted early face the obstacle of late frosts, which hinder the attainment of an optimal total sugar content. On the other hand, crops that are planted late encounter the challenge of a shortened growing season, which affects the process of sugar synthesis. Establishing optimal conditions for achieving an ideal total sugar content is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions for improving the resilience of crops. These interventions can affect the total sugar content and influence the crop's overall photosynthetic efficiency and yield potential. Investigating total sugar content and environmental stressors in the agricultural domain provides valuable insights into the complex mechanisms regulating crop development's vegetative and reproductive phases.

Table 4.4.3.1. Effect of treatments on total soluble sugar of maize seeds (microgram/ml) during spring season 2022 and 2023

Treatments	Total soluble sugar-2022	Total soluble sugar-2023
Sowing Date		
SE -Early sowing	8.79	8.95
S0 -Optimum sowing	54.02	54.19
SL -Late sowing	58.20	58.37
Agrochemical		
A0- Control	38.43	38.59
A1-Sodium nitroprusside (250 µM/L)	43.57	43.73
A2-Salicylic acid (150mg/L)	40.47	40.63
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	38.89	39.06
Alpha at 0.05		
CV (Sowing date and agrochemical)	5.09	8.36
CV (Sowing)	5.84	9.15
CD (Agrochemical)	2.29	2.28
CD (Sowing)	3.28	3.25

Table 4.4.3.2 The interaction effect of treatments on total soluble sugar of maize seeds (microgram/ml) during spring season of 2022 and 2023

Treatments	Total soluble sugar-2022	Total soluble sugar-2023
SEA0	7.16^{d}±0.68	7.00^{c}±0.68
SEA1	14.58^{c}±9.18	14.42^{b}±9.18
SEA2	6.79^{b}±0.88	6.63^{ab}±0.88
SEA3	7.30^{a}±0.99	7.14^{c}±0.99
S0A0	53.95^{e}±2.43	53.79^{h}±2.43
S0A1	57.15^{e}±1.13	56.99^{fg}±1.13
S0A2	54.36^{fg}±2.14	54.20^{a}±2.14
S0A3	51.30^{i}±0.75	51.14^{g}±0.75
SLA0	54.66^{gh}±4.31	54.50^{g}±4.31
SLA1	59.48^{f}±1.53	59.32^{d}±1.53
SLA2	60.76^{fg}±0.50	60.59^{ef}±0.50
SLA3	58.58^{h}±0.40	58.42^{de}±0.40
CV	5.09	8.36
CD	5.40	5.40

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.4.3.1a. Effect of sowing dates and agrochemicals treatments on total soluble sugar of maize seeds (micro gram/ml) during spring season 2022

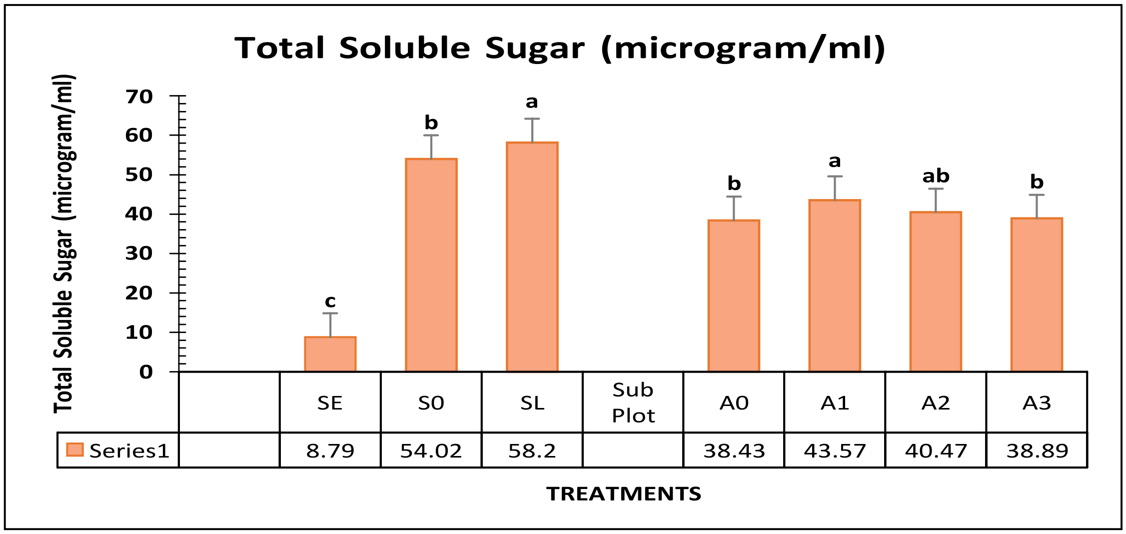
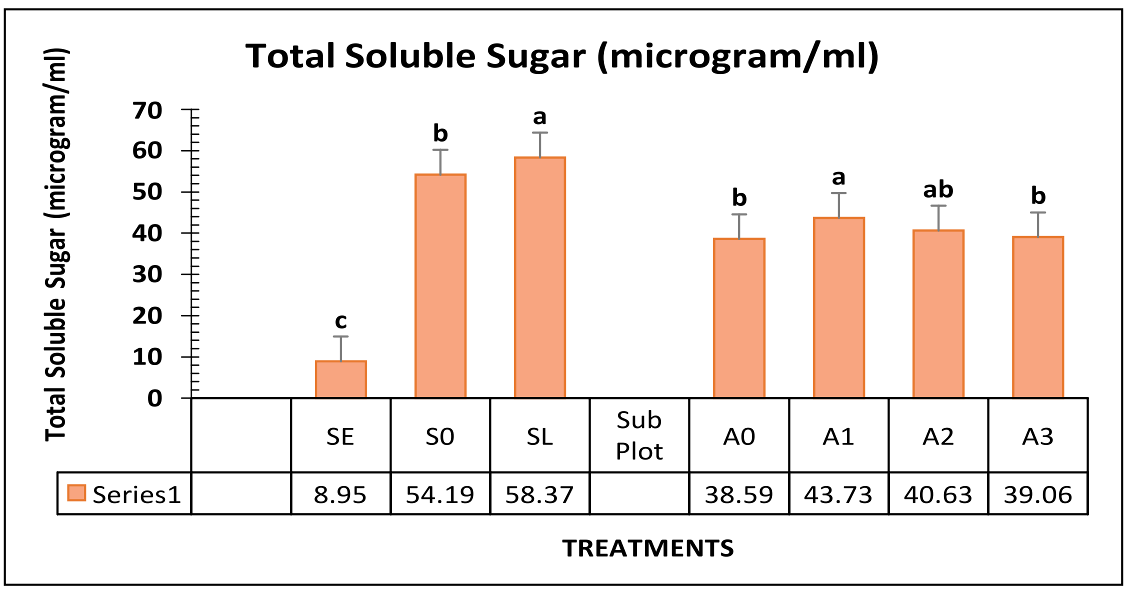


Figure 4.4.3.2b. Effect of sowing dates and agrochemicals treatments on total soluble sugar of maize seeds (microgram/ml) during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.4.4 Total Soluble Protein (microgram/ml): The impact of different sowing dates and different agrochemicals on Total Soluble Protein (microgram/ml) from seed at harvest is shown in (Table 4.4.4.1, 4.4.4.2 and Figure 4.4.4.1a, 4.4.4.2b). In 2022 and 2023, there was a significant difference in the Total Soluble Protein (microgram/ml) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Total Soluble Protein (microgram/ml) was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage increased by 26.88%; in late sowing, it decreased by 30.51% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) increased the percentage by 7.19% compared to the control (A0). When compared to the control (A0), the administration of salicylic acid (A2) produced a superior effect, increasing the rate by 2.82%. In comparison to the control (A0), the combination administration of sodium nitroprusside as well as salicylic acid (A3) raised the rate by 7.72%. In 2023, it was also found that early sowing (SE) increased the percentage by 25.03% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate decreased by 28.48% compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) increased the percentage by 6.90% compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 2.90% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 7.63% compared to the control (A0). The complex network of environmental stressors impacting the overall concentration of soluble proteins in crops unveils a sophisticated interaction among multiple factors, with particular emphasis on the timing of planting. Sowing seeds earlier or later than the recommended schedule poses distinct challenges that significantly impact plant synthesis of soluble proteins. Comprehending these fluctuations is imperative in deciphering the intricate correlation between environmental stressors, the timing of germination, and the subsequent growth and reproductive processes of crops. Sowing seeds at an early stage exposes the emerging seedlings to a wide range of environmental stressors, significantly impacting total soluble protein production. Late spring frosts are stressors that can pose a considerable threat, as they can potentially disrupt the delicate equilibrium of protein production (Ahmad et al., 2013; Miura and Tada 2014; Sharma and Saxena 2002; Prakash et al., 2021; Tripathi et al., 2018; Rai et al., 2018; Li et al., 2017; Meena et al., 2018). Low temperatures hinder essential physiological mechanisms, such as the metabolic pathways associated with the synthesis of proteins. This phenomenon has a measurable effect on soluble proteins' overall quantity and efficiency. The impact of cold stress is apparent in crops planted early, as it decreases soluble protein content and disrupts their photosynthetic efficiency, thereby impeding their subsequent growth. On the other hand, sowing crops later than usual introduces a distinct array of environmental stress factors that impact the overall concentration of soluble proteins in the crops. The compressed duration of the growing season places considerable stress on plants, compelling them to accelerate both their vegetative and reproductive growth. In the given situation, the condensed period may potentially reduce the overall concentration of soluble proteins. This can occur as plants expedite their growth stages to allocate resources towards reproductive processes. Tangible time constraints hinder the ability of crops to maximise their overall soluble protein content. This underscores the importance of maintaining an optimal soluble protein content amidst fluctuating environmental stressors that arise from deviations in recommended sowing timing. The timing of sowing, as instructed, is of utmost importance in the scientific study of total soluble protein content, as it establishes the most favourable conditions for the growth and development of crops. The temporal coincidence corresponds to advantageous ecological circumstances, encompassing temperature, soil moisture, and duration of daylight, all of which collectively contribute to the optimal process of protein synthesis (Kaczynski et al., 2016; Salam et al., 2022; Shi et al., 2019; Blackwell et al., 2018; Zhang et al., 2019; Costa et al., 2022; Dwivedi et al., 2013; Cui et al., 2012). The synchronisation method facilitates the prompt activation of genetic and hormonal mechanisms, resulting in a consistent and optimal total soluble protein content level. The suggested timing establishes the foundation for attaining an optimal photosynthetic equilibrium, a crucial factor in determining the crop's overall development and efficiency. A systematic approach is employed to investigate the influence of growth regulators to address the consequences of environmental stress on the overall concentration of soluble proteins. Salicylic acid, well-known for its role in plant defence mechanisms, can be utilised to regulate protein synthesis during unfavourable circumstances. This strategic approach becomes especially pertinent for crops that are sown early, as it provides a method to enhance the resilience of plants against the potential adverse impacts of late frosts on the process of protein synthesis. Salicylic acid's activation of stress response genes has been found to enhance the plant's capacity to endure environmental challenges, which may contribute to a more consistent and optimal total soluble protein content. In addition, using sodium nitroprusside as a nitric oxide donor presents an intervention strategy to optimise the overall range of soluble proteins. When sodium nitroprusside is used carefully and deliberately, it impacts vital physiological processes, including cell division and elongation, which are essential for the production of proteins. This application aids in achieving an ideal level of total soluble protein content, which is particularly advantageous for crops that are sown late and need to enhance both vegetative and reproductive growth despite a shorter growing season. The intricate utilisation of these growth regulators exemplifies their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from suggested sowing timing. The investigation into the impact of environmental stress on the overall concentration of soluble proteins in crops provides a comprehensive comprehension of the complex interaction between factors such as timing, growth conditions, and the development of both vegetative and reproductive components (Yadav et al., 2018; Ghazi 2017; Naseem et al., 2020; Prakash et al., 2021). Crops that are sown early face the obstacle of late frosts, which hinder the attainment of an optimal total soluble protein content. On the other hand, crops that are planted late encounter the stress of a condensed growing season, affecting the protein synthesis process. Establishing optimal conditions for achieving an ideal total soluble protein content is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions to improve crops' resilience. These interventions have the potential to impact the overall growth and productivity of the crop by influencing the content of total soluble proteins. This scientific investigation illuminates the environmental stress factors encountered by crops. It offers a framework for deliberate interventions to address these challenges and enhance the concentration of soluble proteins for resilient crop growth.

Table 4.4.4.1. Effect of treatments on total soluble protein of maize seeds (microgram/ml) during spring season 2022 and 2023

Treatments	Total soluble Protein-2022	Total soluble Protein-2023
Sowing Date		
SE -Early sowing	5.68	5.79
S0 -Optimum sowing	1.54	1.65
SL -Late sowing	1.07	1.18
Agrochemical		
A0- Control	2.64	2.75
A1-Sodium nitroprusside (250 µM/L)	2.83	2.94
A2-Salicylic acid (150mg/L)	2.72	2.83
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	2.85	2.96
Alpha at 0.05		
CV (Sowing date and agrochemical)	5.09	4.90
CV (Sowing)	5.84	5.61
CD (Agrochemical)	0.18	0.19
CD (Sowing)	0.13	0.12

Table 4.4.4.2 The interaction effect of treatments on total soluble protein of maize seeds (microgram/ml) during the spring season of 2022 and 2023

Treatments	Total soluble protein-2022	Total soluble protein-2023
SEA0	4.64^{g}±0.42	4.75^{d} ±0.41
SEA1	4.97^{g}±0.03	5.08^{c}±0.02
SEA2	5.75^{f}±0.14	5.86^{b} ±0.18
SEA3	7.38^{g}±0.08	7.49^{a}±0.09
S0A0	2.28^{c}±0.11	2.39^{e} ±0.19
S0A1	2.25^{d}±0.07	2.37^{e} ±0.05
S0A2	1.27^{b}±0.08	1.38^{fg} ±0.07
S0A3	0.37^{g}±0.03	0.48^{i} ±0.08
SLA0	1.03^{e}±0.06	1.14^{gh}±0.09
SLA1	1.28^{c}±0.07	1.39^{f}±0.02
SLA2	1.16^{ab}±0.10	1.27^{fg} ±0.13
SLA3	0.83^{a}±0.14	0.94^{h} ±0.17
CV	5.09	4.90
CD	0.27	0.28

Where data is shown as Mean±SD with Duncan at p<0.05; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.4.4.1a. Effect of sowing dates and agrochemicals treatments on total soluble protein of maize seeds (microgram/ml) during spring season 2022

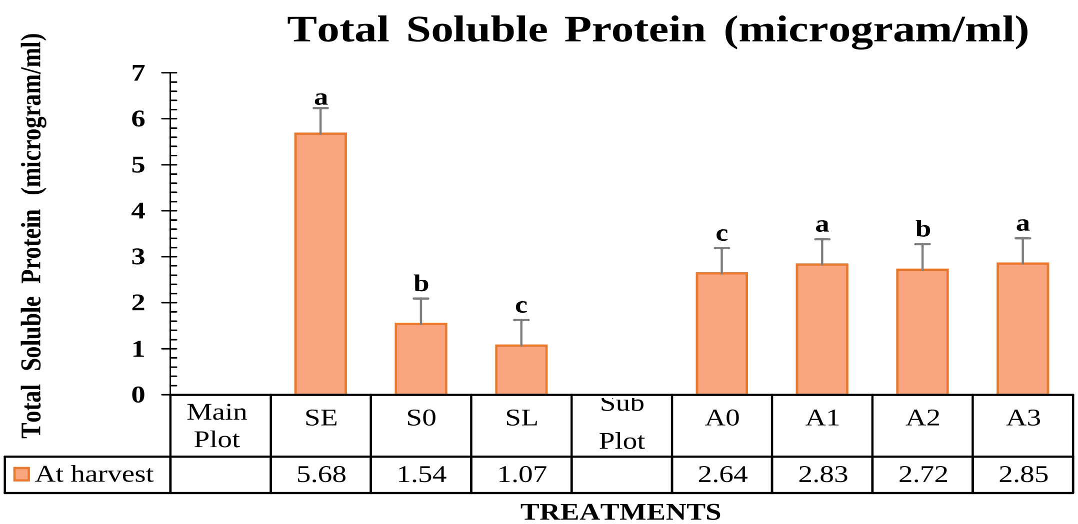
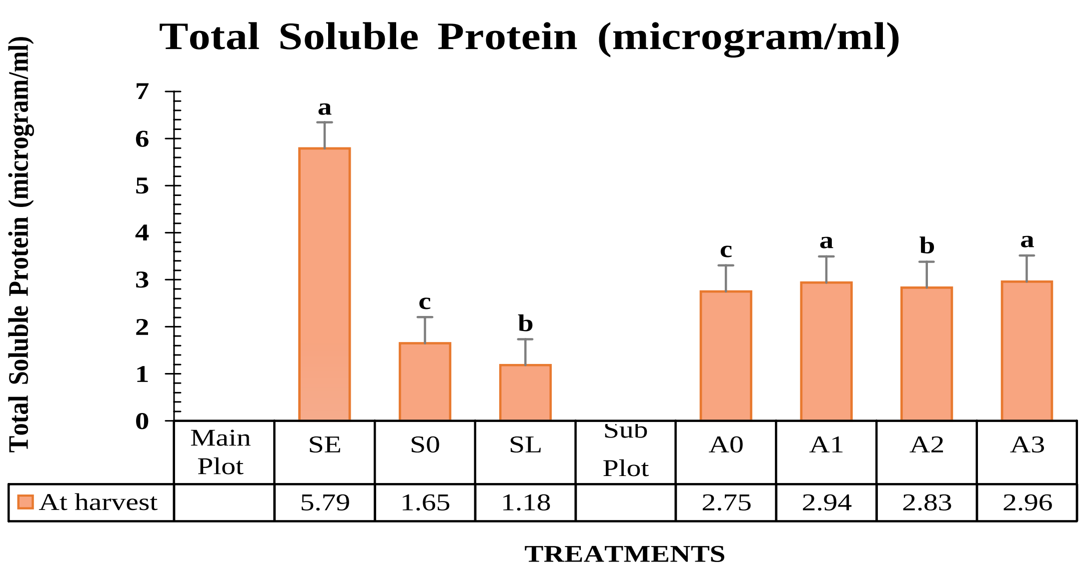


Figure 4.4.4.2b. Effect of sowing dates and agrochemicals treatments on total soluble protein of maize seeds (microgram/ml) during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.4.5 Total Starch (microgram/ml): The impact of different sowing dates and agrochemicals on Total Starch (microgram/ml) from seed at harvest is shown in (Table 4.4.5.1, 4.4.5.2, and Figure 4.4.5.1a, 4.4.5.2b). In 2022 and 2023, there was a significant difference in the Total Starch (microgram/ml) sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Total Starch (microgram/ml) was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 25.83%, and in late sowing, it decreased by 13.17% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) increased the percentage by 28.98% compared to the control (A0). The application of salicylic acid (A2) showed a better result, increasing the rate by 43.15% compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the speed by 22.70% compared to the control (A0). In 2023, it was also found that early sowing (SE) decreased the percentage by 25.86% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate decreased by 14.92% compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) increased the percentage by 30.68% compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 59.66% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 38.96% compared to the control (A0). Within the complex realm of crop physiology, the assessment of overall starch content is a significant indicator, offering valuable insights into the adaptive responses of plants to diverse environmental stressors. This study aims to investigate the intricate dynamics of total starch content in crops subjected to untimely sowing, either prematurely or delayed, compared to the planting schedule recommended by experts. Comprehending the fluctuations in overall starch concentration is crucial for elucidating the influence of environmental factors, timing of germination, and subsequent growth and reproductive processes. Sowing seeds at an early stage introduces a sequence of environmental stress factors that substantially impact the overall starch content found in newly emerging seedlings (Prakash et al., 2021; Tripathi et al., 2018; Rai et al., 2018; Li et al., 2017; Sanp and Singh 2018; Gholipoor et al., 2013; Meena et al., 2018; Souza et al., 2015; Vetter et al., 2023; Bhattacharya 2019b; Kanso et al., 2023). The potential disruption of metabolic processes crucial for starch synthesis becomes evident due to the imminent threat of late spring frosts. Exposure to low temperatures has been found to disrupt essential physiological functions, thereby affecting the enzymatic activities involved in starch synthesis. In the context of crops sown early, the reduced total starch content becomes a noteworthy concern, as it can disrupt the equilibrium of energy reserves and hinder the overall growth and development of plants. On the other hand, the act of sowing crops late brings about a specific array of environmental stress factors that significantly impact the overall starch content in crops. The compressed duration of the growing season places significant demands on plants to accelerate their vegetative and reproductive growth. During this tight period, there is a possibility of a trade-off in the overall amount of starch present in plants as they expedite their growth stages and allocate resources towards reproductive processes. Their time constraints limit the ability of crops to maximise their general starch content. This highlights the importance of maintaining a precise equilibrium to attain an optimal starch content distribution in diverse environmental stressors linked to deviations from the suggested planting schedule. The timing of sowing is considered a crucial element in the scientific investigation of total starch content, as it determines the ideal conditions for crop growth and development. The timing of this phenomenon corresponds with advantageous environmental factors, such as optimal temperature, adequate soil moisture, and extended daylight duration, all of which contribute to the efficient process of starch synthesis. Synchronization facilitates the prompt initiation of genetic and hormonal mechanisms, resulting in consistent and optimal accumulation of total starch content (Prakash et al., 2021; Bhandari et al., 2018; Rai et al., 2018; Li et al., 2017; Sanp and Singh 2018; Amjadian et al.,2013; Meena et al., 2018; Vetter et al., 2023; Bhattacharya 2019b; Kanso et al., 2023; Hook and Sheridan 2020). The suggested timing establishes the foundation for optimal metabolic equilibrium, a crucial factor influencing the crop's overall development and efficiency. To alleviate the effects of environmental stress on the general starch content, a strategic approach is employed to investigate the influence of growth regulators. Salicylic acid, well-known for its role in plant defence mechanisms, can regulate starch synthesis in unfavourable circumstances. The utilisation of this strategic approach gains significance in the context of crops that are sown early, as it provides a method to enhance the resilience of plants against the potential adverse impacts of late frosts on the production of starch. Salicylic acid's activation of stress response genes has been found to enhance the plant's capacity to endure environmental challenges, thereby facilitating a more consistent and ideal total starch content profile. In addition, using sodium nitroprusside, which acts as a donor of nitric oxide, offers an intervention for enhancing overall starch content. When sodium nitroprusside is used carefully and deliberately, it impacts critical physiological processes, specifically starch synthesis, which is essential for the overall production of total starch content. This application aids in the determination of ideal starch levels, which is particularly advantageous for crops that are sown late and need to promote both vegetative and reproductive growth within a limited growing season. The intricate utilization of these growth regulators underscores their capacity to regulate the physiological reactions of crops confronting environmental stressors linked to deviations from the recommended sowing schedule (Choudhary et al., 2019; Kumar and Goh 1999; Souza et al., 2015; Vetter et al., 2023; Bhattacharya 2019b; Kanso et al., 2023; Hook and Sheridan 2020; Motyka et al., 2023; Kordi et al., 2023; Sim and Nyam 2021; Ahmad et al., 2022; Yajie Zhang and Niu 2016; Watson et al., 2017; Lei et al., 2023). The investigation into the impact of environmental stress on the overall starch content in crops provides a comprehensive comprehension of the complex interaction between timing, growth conditions, and the development of both vegetative and reproductive aspects. Crops planted early encounter difficulties due to late frosts, which hinder the development of optimal starch content. Conversely, crops planted late experience the pressure of a shortened growing season, which affects their metabolic processes. Establishing optimal conditions for achieving an ideal total starch content profile is contingent upon adhering to the recommended sowing timing based on scientific principles. Incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methodologies presents strategic interventions aimed at bolstering the resilience of crops. These interventions have the potential to impact starch levels, as well as influence the overall metabolic equilibrium and productivity of the crop. This scientific investigation illuminates the environmental stress factors encountered by crops. It presents a framework for strategic interventions to address these challenges and enhance overall starch content for resilient crop growth.

Table 4.4.5.1 Effect of treatments on total starch of maize seeds (microgram/ml) during spring season 2022 and 2023

Treatments	Total Starch - 2022	Total Starch - 2023
Sowing Date		
SE -Early sowing	27.87	27.52
S0 -Optimum sowing	37.58	37.12
SL -Late sowing	32.63	31.58
Agrochemical		
A0- Control	25.15	24.15
A1-Sodium nitroprusside (250 µM/L)	32.44	31.56
A2-Salicylic acid (150mg/L)	39.15	38.56
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	34.04	33.56
Alpha at 0.05		
CV (Sowing date and agrochemical)	14.32	13.58
CV (Sowing)	6.43	6.48
CD (Agrochemical)	2.38	2.35
CD (Sowing)	4.63	4.59

Table 4.4.5.2 Interaction effect of treatments on total starch of maize seeds (microgram/ml) during the spring season of 2022 and 2023

Treatments	Total Starch-2022	Total Starch-2023
SEA0	17.91^{f}±0.64	17.87^{f}±0.65
SEA1	24.54^{ef}±0.30	24.50^{ef}±0.34
SEA2	32.23^{cde}±0.61	32.20^{cde}±0.65
SEA3	36.82^{bc}±0.44	36.79^{bc}±0.48
S0A0	29.15^{cde}±6.91	29.11^{cde}±6.93
S0A1	39.87^{ab}±5.62	39.84^{ab}±4.65
S0A2	44.37^{a}±2.24	44.33^{a}±3.14
S0A3	36.94^{abc}±7.83	36.91^{abc}±6.53
SLA0	28.42^{de}±0.80	28.38^{de}±0.70
SLA1	32.91^{bcd}±7.95	32.87^{bcd}±6.55
SLA2	40.86^{ab}±0.75	40.83^{ab}±0.95
SLA3	28.36^{de}±0.58	28.32^{de}±0.38
CV	14.32	13.58
CD	7.33	6.99

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.4.5.1a. Effect of sowing dates and agrochemicals treatments on total starch of maize seeds (microgram/ml) during spring season 2022

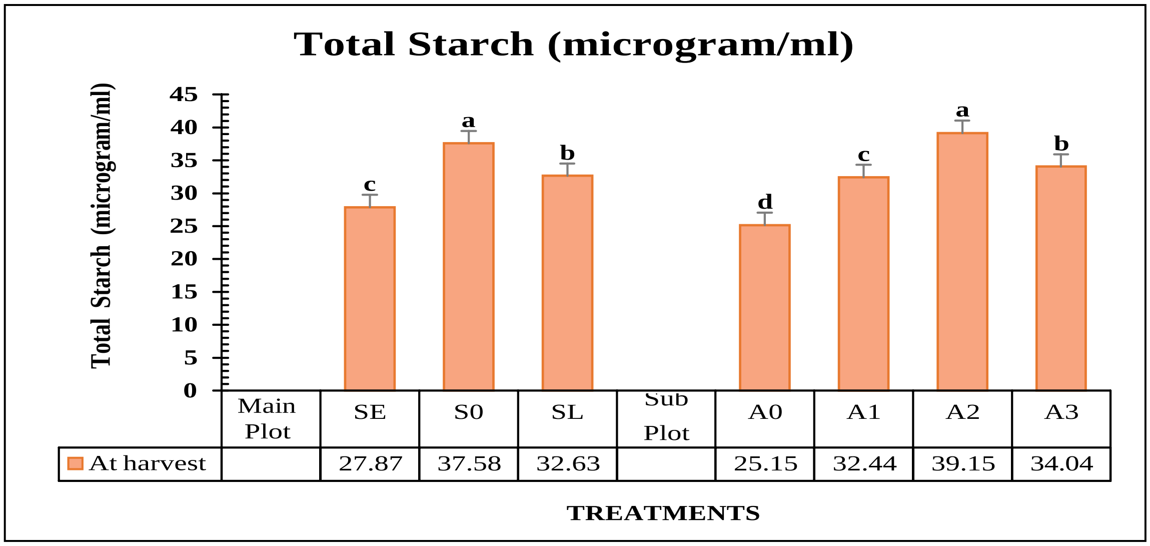
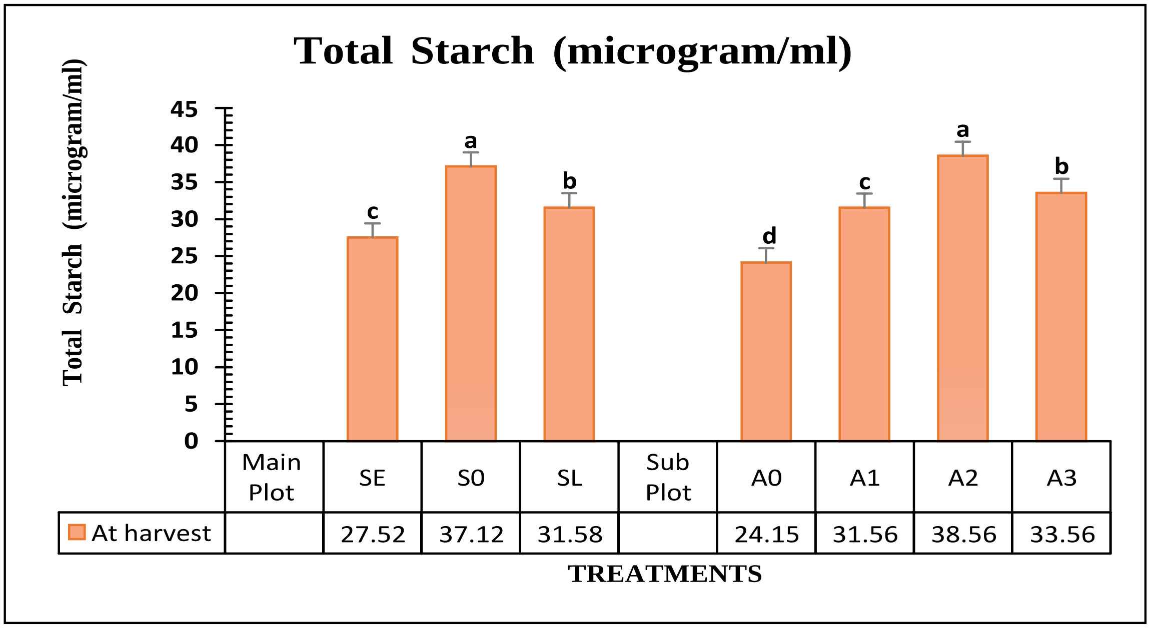


Figure 4.4.5.1a. Effect of sowing dates and agrochemicals treatments on total starch of maize seeds (microgram/ml) during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.4.6 Nitrogen Uptake (ppm/kg): The effect of different sowing dates and agrochemicals on Nitrogen Uptake (ppm/kg) in maize straw at harvest is shown in (Table 4.4.6.1, 4.4.6.2, and Figure 4.4.6.1a, 4.4.6.2b). In 2022 and 2023, there was a significant difference in the Nitrogen Uptake (ppm/kg) in maize straw sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Nitrogen Uptake (ppm/kg) in maize straw was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 0.37%, and in late sowing, it decreased by 4.82% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) increased the percentage by 15.27% compared to the control (A0). The application of salicylic acid (A2) showed a better result by increasing the rate by 7.42% compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the speed by 12.71% compared to the control (A0). In 2023, it was also found that early sowing (SE) decreased the percentage by 0.43% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate decreased by 4.85% compared to the optimum sowing (S0) and in the case of applied agrochemicals, sodium nitroprusside (A1) increased the percentage by 15.26% compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 8.55% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 13.79% compared to the control (A0). The uptake of nitrogen in grains is an essential aspect of crop development because it affects plant growth, yield, and the nutritional quality of the crop as a whole. This investigation delves deeper into the complex factors that affect nitrogen uptake within crops that were sown either too early or too late compared to the recommended planting schedule. It is essential to have a solid understanding of the differences in nitrogen uptake to decipher the influence that environmental conditions, the timing of germination, and subsequent vegetative and reproductive development have. Early sowing starts a chain reaction of ecological stressors that significantly impact the amount of nitrogen emerging seedlings can absorb. The impending danger of late-spring frosts becomes more apparent, which can upset the delicate balance of physiological processes essential for the best possible nitrogen uptake. The presence of cold temperatures disrupts vital metabolic processes, which hurts root development and leads to a reduction in the plant's ability to take in nitrogen. In early-sown crops, decreased nitrogen uptake becomes a pressing concern because it can result in reduced plant vigour, impaired nutrient utilisation, and, ultimately, an effect on overall crop productivity. On the other hand, planting seeds later than expected introduces a unique set of environmental stressors that intricately affect the amount of nitrogen that crops absorb. The shortened growing season places significant pressure on the plant to hasten the development of its vegetative and reproductive parts (Ul-Allah et al., 2023; Pedraza et al., 2020; Sarker et al., 2022; Alfen 2014; Escobar et al., 2020; Niaounakis and Halvadakis 2006; Guha et al., 2021). As plants rush through their developmental stages and direct more resources towards reproductive processes, there is a possibility that the amount of nitrogen they take in will decrease within this compressed time frame. Because time moves forward at such a rapid pace, there are limits placed on the ability of plants to maximise the amount of nitrogen they take in. This highlights the delicate balance that must be maintained to achieve ideal nitrogen uptake despite the various environmental stressors that can be caused by deviating from the recommended sowing timing. During the scientific investigation of nitrogen uptake, the recommended sowing timing has emerged as a crucial component. This helps to ensure that crop growth and development conditions are maximised. This timing coincides with optimal environmental conditions, contributing to effective root development and nitrogen uptake. These conditions include temperature, soil moisture, and daylight availability. The synchronisation makes it possible to activate genetic and hormonal processes at the right moment, resulting in consistent and optimal nitrogen uptake. The optimal uptake of nitrogen is a key factor in determining the crop's overall nutrient status as well as its level of productivity. The timing that is recommended sets the stage for achieving this uptake. Exploring the role of growth regulators is one of the strategic approaches that can be taken to reduce the negative effects of environmental stress on nitrogen uptake. In challenging environments, salicylic acid, which is famous for its role in plant defence responses, can be used to modulate the processes by which the plant takes up nutrients. This tactical application becomes especially relevant for early-sown crops, as it provides a means to fortify plants against the potentially detrimental effects of late frosts on developing nitrogen uptake. Activating stress response genes by salicylic acid increases the plant's ability to withstand environmental stresses, potentially promoting a more uniform and optimal nitrogen uptake. In addition, the utilisation of sodium nitroprusside, which acts in the capacity of a nitric oxide donor, constitutes an intervention that maximises nitrogen uptake. When used appropriately, sodium nitroprusside can influence significant physiological processes, such as the expansion of root systems and the uptake of nutrients. This application helps establish optimal nitrogen uptake, which is especially beneficial for late-sown crops attempting to accelerate reproductive growth within the constraints of a shorter growing season. The complex application of these growth regulators demonstrates their capacity to modulate the physiological responses of crops when confronted with environmental stressors associated with deviations from the recommended sowing timing. Investigating the effects of environmental stress on the uptake of nitrogen by plants provides a comprehensive understanding of the complex relationship between the timing of events, the present growth conditions, and the plant's vegetative and reproductive development. Early-sown crops have to deal with the difficulty of late frosts, which prevents them from developing an optimal capacity for nitrogen uptake (Li and Tao 2023; Yang et al., 2023; Sun et al., 2023; Guo et al., 2023; Sun et al., 2023; Morel et al., 2021; Pedraza et al., 2020). Late-sown crops, on the other hand, have to deal with the stress of a compressed growing season, which affects root development and nitrogen uptake. Based on scientific principles, the recommended sowing timing emerges as a pivotal factor in establishing optimal conditions for achieving ideal nitrogen uptake. This is because the recommended sowing timing is crucial in selecting optimal conditions. Incorporating growth regulators into scientific methods, such as salicylic acid and sodium nitroprusside, offers strategic interventions to improve the resilience of crops by influencing the production of nitrogen uptake and shaping the crop's overall nutrient status and productivity. This scientific investigation not only sheds light on the environmental stressors that crops face but also provides a pathway for strategic interventions that can be used to navigate these challenges and optimise nitrogen uptake to facilitate robust crop development.

Table 4.4.6.1 Effect of treatments on nitrogen uptake content of maize straw (ppm/kg) at harvest during spring season 2022 and 2023

Treatments	Nitrogen uptake-2022	Nitrogen uptake-2023
Sowing Date		
SE -Early sowing	24393	24400
S0 -Optimum sowing	24486	24507
SL -Late sowing	23304	23318
Agrochemical		
A0- Control	21992	22006
A1-Sodium nitroprusside (250 µM/L)	25352	25366
A2-Salicylic acid (150mg/L)	23874	23888
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	25027	25041
Alpha at 0.05		
CV (Sowing date and agrochemical)	0.01	0.01
CV (Sowing)	0.01	0.01
CD (Agrochemical)	2.15	2.16
CD (Sowing)	2.81	2.85

Table 4.4.6.2 Interaction effect of treatments on nitrogen uptake of maize straw (ppm/kg) at harvest during the spring season of 2022 and 2023

Treatments	Nitrogen uptake-2022	Nitrogen uptake-2023
SEA0	21870.00^{i}±6.56	21856.00^{i}±6.51
SEA1	25634.33^{c}±4.04	25622.00^{c}±1.73
SEA2	24588.00^{e}±6.56	24574.00^{e}±6.45
SEA3	25906.33^{a}±3.51	25892.33^{a}±3.51
S0A0	23564.67^{g}±4.62	23550.67^{g}±4.35
S0A1	25877.00^{b}±4.58	25863.33^{b}±4.04
S0A2	23581.33^{f}±4.04	23568.00^{f}±3.00
S0A3	24607.00^{d}±6.56	24594.67^{d}±6.45
SLA0	20582.33^{j}±3.51	20568.33^{j}±3.54
SLA1	24585.33^{e}±4.93	24571.33^{e}±4.95
SLA2	23494.67^{h}±5.69	23480.67^{h}±5.59
SLA3	24610.33^{d}±7.51	24596.33^{d}±7.51
CV	0.01	0.01
CD	4.71	4.73

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.4.6.1a. Effect of sowing dates and agrochemicals treatments on nitrogen uptake content of maize straw (ppm/kg) at harvest during spring season 2022

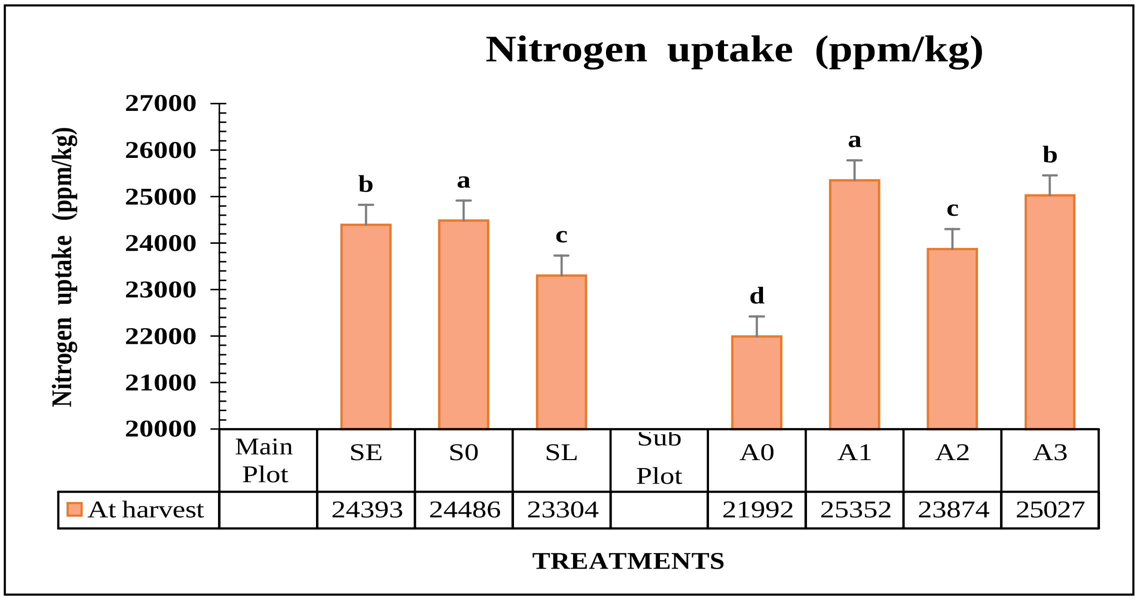
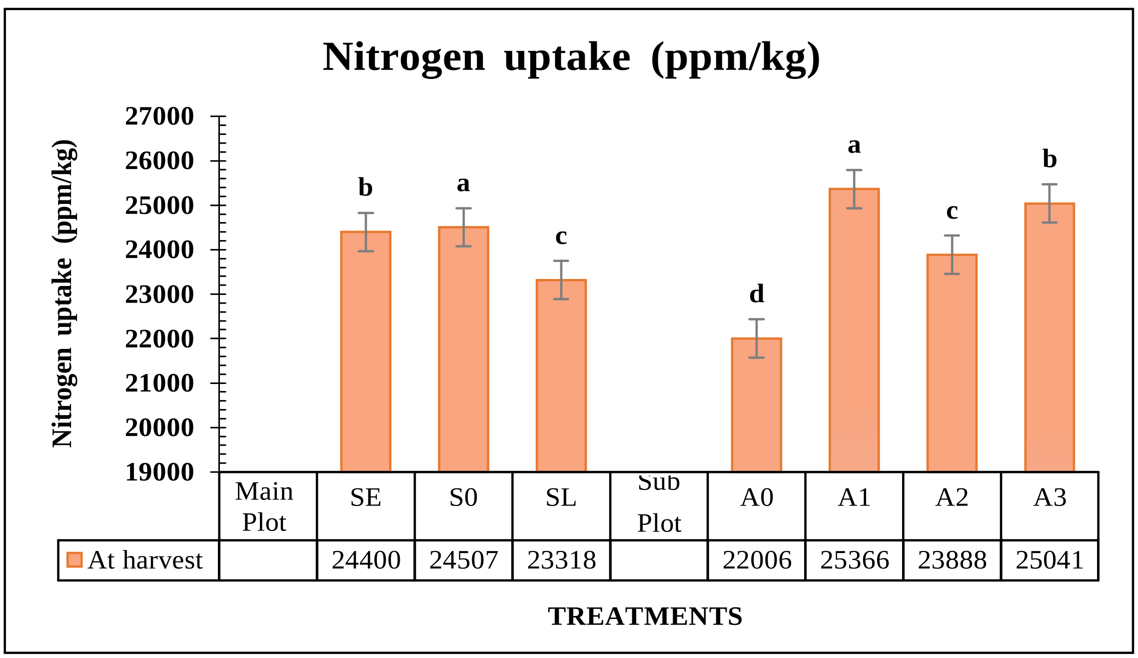


Figure 4.4.6.2b. Effect of sowing dates and agrochemicals treatments on nitrogen uptake content of maize straw (ppm/kg) at harvest during spring season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.4.7 Phosphorus Uptake (ppm/kg): The effect of different sowing dates and agrochemicals on Phosphorus Uptake (ppm/kg) in maize straw at harvest is shown in (Table 4.4.7.1, 4.4.7.2, 4.4.7.3 and 4.4.7.4 and Figure 4.4.7.1a, 4.4.7.2b). In 2022 and 2023, there was a significant difference in the Phosphorus Uptake (ppm/kg) in maize straw sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Phosphorus Uptake (ppm/kg) in maize straw was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 0.11%, and in late sowing, it decreased by 1.96% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) increased the percentage by 34.79% compared to the control (A0). The application of salicylic acid (A2) showed a better result by increasing the rate by 23.38% compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the speed by 21.47% compared to the control (A0). In 2023, it was also found that early sowing (SE) decreased the percentage by 0.11% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate decreased by 1.95% compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) increased the percentage by 34.71% compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 31.44% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 28.17% compared to the control (A0). The uptake of phosphorus by grains is an essential factor that influences plant development, yield, and the nutritional quality of the crop as a whole. Compared to the suggested planting schedule, this investigation delves into the complex factors that influence the amount of phosphorus taken in by crops subjected to untimely sowing, either too early or too late. It is essential to have a solid understanding of the differences in phosphorus uptake to decipher the impact that environmental conditions, the timing of germination, and subsequent vegetative and reproductive development have on a plant. The practice of early sowing kicks off a chain reaction of environmental stressors that significantly impact the amount of phosphorus taken up by newly emerging seedlings (Buerkert et al., 2023; Fan et al., 2023; Chen et al., 2023; LI et al., 2023; Zhang et al., 2023; Lairez et al., 2023; Li et al., 2023; Dong et al., 2023). The impending danger of late-spring frosts becomes more apparent, which can upset the delicate equilibrium of physiological processes essential for optimal phosphorus absorption. The presence of cold temperatures disrupts crucial metabolic processes, which hurts root development and leads to a reduction in the amount of phosphorus that can be absorbed. In early-sown crops, decreased phosphorus uptake becomes a pressing concern because it can result in reduced plant vigour, impaired nutrient utilization, and, ultimately, an impact on overall crop productivity. On the other hand, planting seeds later than expected introduced a unique set of environmental stressors that intricately affect the amount of phosphorus that crops absorb. The shortened growing season places significant pressure on the plant to hasten the development of its vegetative and reproductive parts. As plants speed through their developmental stages and direct more resources towards their reproductive processes, there is a possibility that the amount of phosphorus they absorb will decrease within this compressed time frame. The brevity of time limits plants' capacity to maximize the amount of phosphorus they take in, limiting crop yield. This highlights the delicate balance that must be maintained to achieve ideal phosphorus uptake despite the various environmental stressors associated with deviations from the recommended sowing timing. The scientific investigation of phosphorus uptake reveals that the recommended sowing timing is a significant factor in establishing ideal conditions for the expansion and maturation of crops. This timing coincides with optimal environmental conditions, including temperature, soil moisture, and the amount of daylight available, all of which contribute to effective root development and phosphorus uptake. The synchronizations makes it possible to activate genetic and hormonal processes at the right moment, resulting in consistent and efficient phosphorus uptake. The optimal uptake of phosphorus is a critical factor in determining the overall nutrient status of the crop as well as its level of productivity. The timing that is recommended sets the stage for achieving this uptake. Exploring the role of growth regulators is one of the strategic approaches that can be taken to reduce the negative impact of environmental stress on phosphorus uptake. In challenging environments, salicylic acid, which is famous for its role in plant defence responses, can be used to modulate the processes by which the plant takes up nutrients. This tactical application becomes especially relevant for early-sown crops, as it provides a means to fortify plants against the potentially detrimental effects of late frosts on the development of phosphorus uptake. Activating stress response genes by salicylic acid increases the plant's ability to withstand environmental stresses, potentially promoting a more uniform and optimal phosphorus uptake. In addition, the use of sodium nitroprusside, which acts as a donor of nitric oxide, is an intervention that can increase the amount of phosphorus that the plant takes in. When used appropriately, sodium nitroprusside can influence significant physiological processes, such as the expansion of root systems and the uptake of nutrients. This application helps establish optimal phosphorus uptake, which is especially beneficial for late-sown crops attempting to accelerate reproductive growth within the constraints of a shorter growing season. The complex application of these growth regulators demonstrates their capacity to modulate the physiological responses of crops when confronted with environmental stressors associated with deviations from the recommended sowing timing. Investigating the effects of environmental stress on phosphorus uptake in plants provides a comprehensive understanding of the complex interaction between the timing of vegetative and reproductive development and the present growth conditions (Wang et al., 2023; Qiu et al., 2023; Ling et al., 2023). Early-sown crops have to deal with the difficulties of late frosts, which prevent optimal phosphorus uptake. In contrast, late-sown crops have to deal with the challenges of a compressed growing season, which influences root development and phosphorus uptake. Based on scientific principles, the recommended sowing timing emerges as a pivotal factor in establishing optimal conditions for achieving ideal phosphorus uptake. Incorporating growth regulators into scientific approaches, such as salicylic acid and sodium nitroprusside, offers strategic interventions to enhance the resilience of crops, influencing the production of phosphorus uptake and shaping the crop's overall nutrient status and productivity. This scientific investigation not only sheds light on the environmental stressors that crops face but also provides a pathway for strategic interventions that can be used to navigate these challenges and optimize phosphorus uptake to facilitate robust crop development.

Table 4.4.7.1 Effect of treatments on phosphorus uptake of maize straw (ppm/kg) at harvest during Spring season 2022 and 2023

Treatments	Phosphorus uptake-2022	Phosphorus uptake-2023
Sowing Date		
SE -Early sowing	4171.7	4179.7
S0 -Optimum sowing	4176.5	4184.5
SL -Late sowing	4094.5	4102.5
Agrochemical		
A0- Control	3354.6	3362.6
A1-Sodium nitroprusside (250 µM/L)	4521.9	4529.9
A2-Salicylic acid (150mg/L)	4411.9	4419.9
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	4301.9	4309.9
Alpha at 0.05		
CV (Sowing date and agrochemical)	0.29	0.28
CV (Sowing)	0.42	0.41
CD (Agrochemical)	19.67	19.68
CD (Sowing)	11.88	11.86

Table 4.4.7.2 Interaction effect of treatments on phosphorus uptake of maize straw (ppm/kg) at harvest during the spring season of 2022 and 2023

Treatments	Phosphorus uptake 2022	Phosphorus uptake 2023
SEA0	3265.33^{g}±11.59	3257.33^{g}±11.25
SEA1	4554.33^{a}±15.04	4546.33^{a}±15.46
SEA2	4466.33^{b}±5.51	4458.33^{b}±5.24
SEA3	4432.67^{c}±12.06	4424.67^{c}±12.14
S0A0	3659.33^{f}±15.18	3651.33^{f}±15.67
S0A1	4460.33^{b}±11.93	4452.33^{b}±11.45
S0A2	4361.33^{d}±8.33	4353.33^{d}±8.45
S0A3	4257.00^{e}±20.42	4249.00^{e}±19.45
SLA0	3163.00^{h}±19.52	3155.00^{h}±12.11
SLA1	4575.00^{a}±12.00	4567.00^{a}±14.56
SLA2	4432.00^{c}±14.53	4424.00^{c}±14.45
SLA3	4240.00^{e}±14.73	4232.00^{e}±14.56
CV	0.29	0.28
CD	26.29	26.31

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.4.7.1a. Effect of sowing dates and agrochemicals treatments on phosphorus uptake of maize straw (ppm/kg) at harvest during Spring season 2022

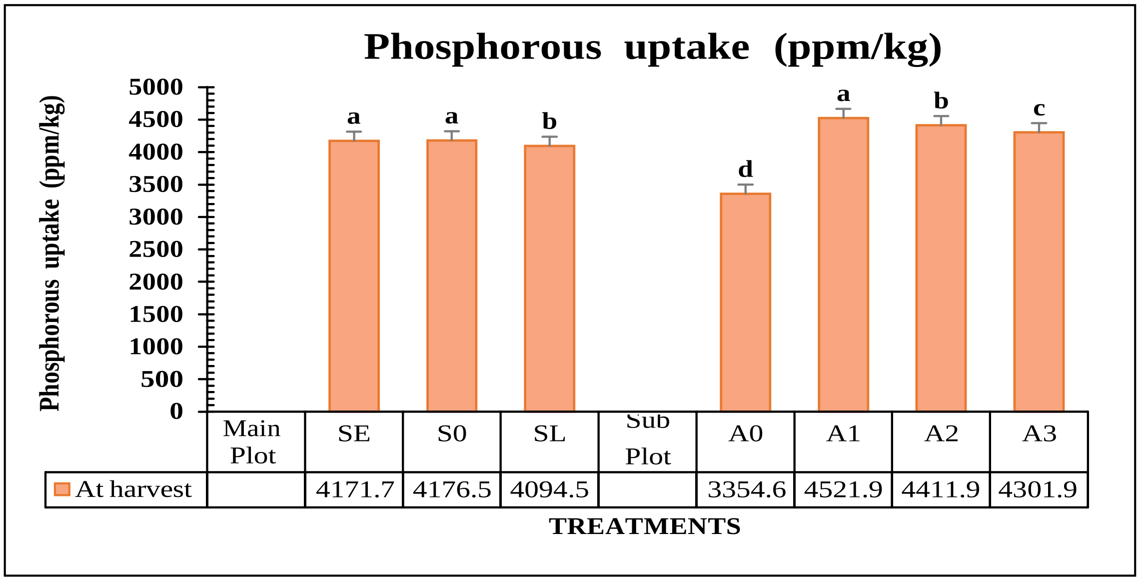
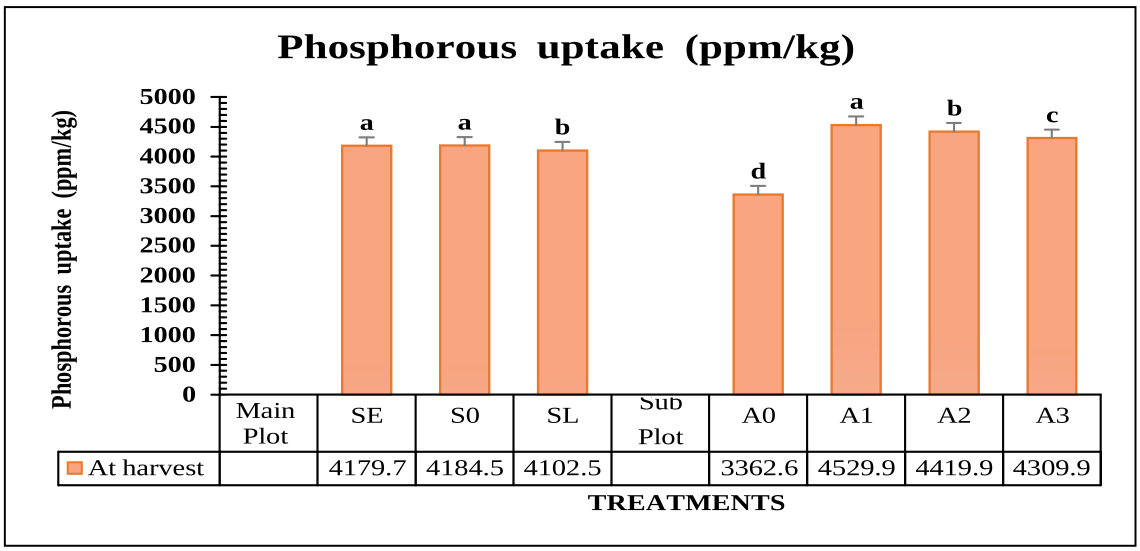


Figure 4.4.7.2b. Effect of sowing dates and agrochemicals treatments on phosphorus uptake of maize straw (ppm/kg) at harvest during Spring season 2023



Where data is shown as Mean±SD with Duncan at p<0.05; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.4.8 Potassium Uptake (ppm/kg): The impact of varying planting dates and agrochemicals on Potassium Uptake (ppm/kg) in maize straw at harvest is shown in (Table 4.4.8.1 and 4.4.8.4 and Figure 4.4.8.1a, 4.4.8.2b). In 2022 and 2023, there was a significant difference in the Potassium Uptake (ppm/kg) in maize straw sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in the case of different sowing dates. In the case of agrochemicals, it was estimated by comparing all the standards with control. Thus, the percentage pattern in the Potassium Uptake (ppm/kg) in maize straw was observed at harvest. In 2022, it was recorded that in early sowing (SE), the percentage decreased by 6.02%, and in late sowing, it decreased by 4.98% compared to the optimum sowing (S0). Among the agrochemicals, the application of sodium nitroprusside (A1) increased the percentage by 19.44% compared to the control (A0). The application of salicylic acid (A2) showed a better result by increasing the rate by 15.82% compared to the control (A0). The combined application of sodium nitroprusside and salicylic acid (A3) increased the percentage by 11.60% compared to the control (A0). In 2023, it was also found that early sowing (SE) decreased the percentage by 6.21% compared to the optimum sowing (S0). In the case of late sowing (SL), the rate fell by 0.25% compared to the optimum sowing (S0). In the case of applied agrochemicals, sodium nitroprusside (A1) increased the percentage by 18.75% compared to the control (A0). The application of salicylic acid showed a better result by increasing the rate by 25.56% compared to the control (A0). Similarly, the combined application of sodium nitroprusside and salicylic acid also showed a better result by increasing the percentage by 12.56% compared to the control (A0). The uptake of potassium by grains is an essential factor in plant development, affecting a variety of physiological processes as well as the overall output of the crop. This investigation delves deeper into the complex factors that affect potassium uptake within crops that were sown either too early or too late compared to the recommended planting schedule. It is essential to have a solid understanding of the variations in potassium uptake to decipher the impact that environmental conditions, the timing of germination, and subsequent vegetative and reproductive development have on the plant. Early sowing starts a chain reaction of ecological stressors that significantly impact the amount of potassium emerging seedlings can absorb. The impending danger of late-spring frosts becomes more apparent, which can throw off the delicate balance of physiological processes essential for the best possible absorption of potassium. The presence of cold temperatures disrupts vital metabolic processes, which hurts root development and leads to a reduction in the plant's ability to absorb potassium. In early-sown crops, decreased potassium uptake becomes a pressing concern because it can result in reduced plant vigour, impaired nutrient utilisation, and, ultimately, an impact on overall crop productivity (Kumar et al., 2023; Singh et al., 2023; Tang et al., 2023; Changjie et al., 2023; Li and Ahammed 2023; Pal et al., 2023; Gunasekera and Ratnasekera 2023; Zahedi et al., 2023). On the other hand, late sowing introduces a distinct set of environmental stressors that intricately influence crop potassium uptake. These stressors can be found in a variety of environments. The shortened growing season places significant pressure on the plant to hasten the development of its vegetative and reproductive parts. As plants rush through their developmental stages and direct more resources towards reproductive processes, their potassium uptake may slow during this compressed period. Because time is of the essence, there are limits placed on the ability of plants to maximize the potassium they take in. This highlights the delicate balance that must be maintained to achieve ideal potassium uptake despite the various environmental stressors caused by deviating from the recommended sowing timing. The scientific investigation of potassium uptake reveals that the recommended sowing timing is a critical factor in establishing optimal conditions for the growth and development of crops. This timing aligns with optimal environmental conditions, contributing to effective root development and potassium uptake. These conditions include temperature, soil moisture, and daylight availability. The synchronizations makes it possible to activate genetic and hormonal processes at the right moment, resulting in consistent and optimal potassium uptake. The optimal uptake of potassium is a critical factor in determining the overall nutrient status of the crop as well as its level of productivity. The timing that is recommended sets the stage for achieving this uptake. A strategic approach investigates the function of growth regulators as a means of mitigating the effect that environmental stress has on the uptake of potassium. In challenging environments, salicylic acid, which is famous for its role in plant defence responses, can be used to modulate the processes by which the plant takes up nutrients. This tactical application becomes especially relevant for early-sown crops, as it provides a means to fortify plants against the potentially detrimental effects of late frosts on the development of potassium uptake. Activating stress response genes by salicylic acid increases the plant's ability to withstand environmental stresses, potentially promoting a more uniform and optimal potassium uptake. In addition, the utilisation of sodium nitroprusside, which acts in the capacity of a nitric oxide donor, constitutes an intervention that maximises potassium uptake. When used appropriately, sodium nitroprusside can influence significant physiological processes, such as the expansion of root systems and the uptake of nutrients (More et al., 2023; Qureshi et al., 2023; Rehman et al., 2023; Laribi et al.,2023; Yadav and Singh 2023; Azizkhani et al., 2023). This application helps establish optimal potassium uptake, which is especially beneficial for late-sown crops attempting to accelerate reproductive growth despite the constraints of a shorter growing season. The complex application of these growth regulators demonstrates their capacity to modulate the physiological responses of crops when confronted with environmental stressors associated with deviations from the recommended sowing timing. Investigating the effects of environmental stress on potassium uptake in plants provides a comprehensive understanding of the complex relationship between the timing of events, the growth circumstances, and the development of vegetative and reproductive structures. Early-sown crops have to deal with the difficulties of late frosts, which prevent the optimal result of potassium uptake. In contrast, late-sown crops must deal with the challenges of a compressed growing season, which influences root development and potassium uptake. Based on scientific principles, the recommended timing of sowing emerges as a pivotal factor in establishing optimal conditions to achieve ideal potassium uptake. By incorporating growth regulators such as salicylic acid and sodium nitroprusside into scientific methods, one can implement strategic interventions to improve the resiliency of crops. These interventions can influence the production of potassium uptake and shape the crop's overall nutrient status and productivity. This scientific investigation sheds light on the environmental stressors that crops face. It provides a pathway for strategic interventions to navigate these challenges and optimise potassium uptake for robust crop development. This is important because potassium deficiency is a major cause of crop failure worldwide.

Table 4.4.8.1 Effect of treatments on potassium uptake of maize straw (ppm/kg) at harvest during spring Season 2022 and 2023

Treatments	Potassium uptake-2022	Potassium uptake-2023
Sowing Date		
SE -Early sowing	8125.6	8769.7
S0 -Optimum sowing	8646.4	8256.3
SL -Late sowing	8215.6	8235.4
Agrochemical		
A0- Control	7245.6	7372.2
A1-Sodium nitroprusside (250 µM/L)	8654.2	8754.8
A2-Salicylic acid (150mg/L)	8615.2	9256.8
A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)	8245.6	8298.8
Alpha at 0.05		
CV (Sowing date and agrochemical)	0.29	0.10
CV (Sowing)	0.42	0.13
CD (Agrochemical)	19.67	12.32
CD (Sowing)	11.88	8.61

Table 4.4.8.2 The interaction effect of treatments on potassium uptake of maize straw (ppm/kg) at harvest during the spring season of 2022 and 2023

Treatments	Potassium uptake-2022	Potassium uptake-2023
SEA0	7561.67[g]±12.01	7555.67[j] ±12.14
SEA1	9130.33[a]±14.01	9124.33[b]±13.25
SEA2	9854.00[b]±16.09	9848.00[a] ±15.09
SEA3	8532.67[c]±17.16	8526.67[g] ±16.14
S0A0	7571.00[f]±22.27	7565.00[j] ±21.25
S0A1	8556.33[b]±17.24	8550.33[f] ±16.45
S0A2	8970.67[d]±21.73	8964.67[c] ±20.25
S0A3	7927.33[e]±8.62	7921.33[i] ±7.65
SLA0	6984.00[h]±20.18	6978.00[k] ±19.54
SLA1	8577.67[a]±17.09	8571.67[e] ±16.12
SLA2	8945.67[c]±23.48	8939.67[d] ±22.08
SLA3	8436.33[e]±21.78	8430.33[h] ±20.78
CV	0.29	0.10
CD	20.54	17.69

Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

Figure 4.4.8.1a. Effect of sowing dates and agrochemicals treatments on potassium uptake of maize straw (ppm/kg) at harvest during spring Season 2022

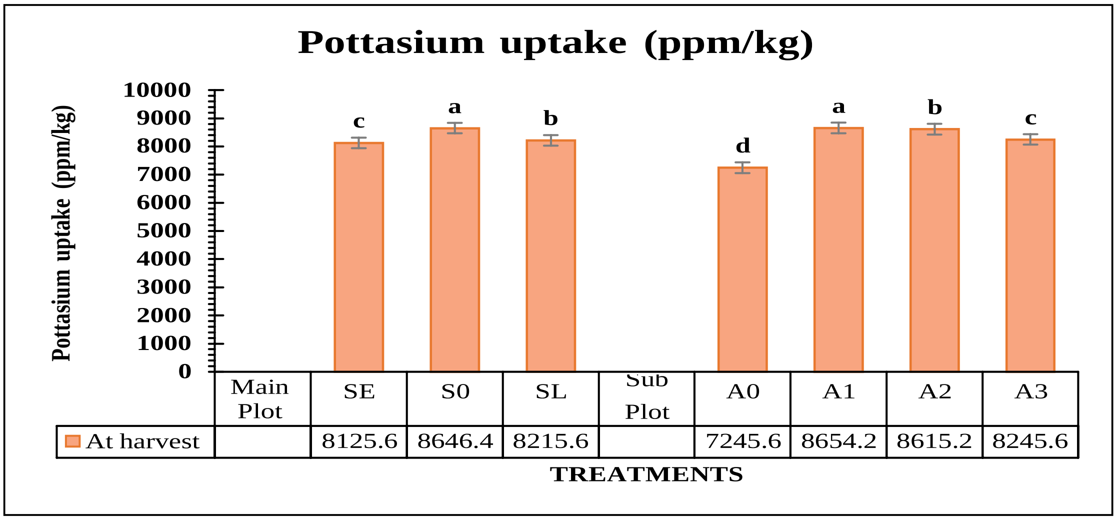
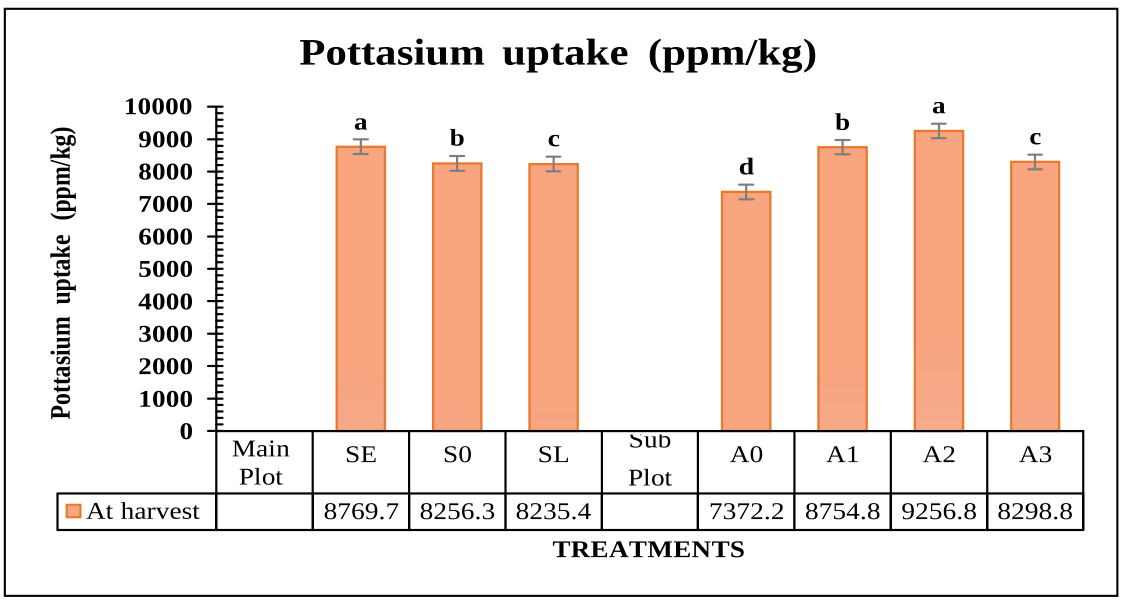


Figure 4.4.8.2b. Effect of sowing dates and agrochemicals treatments on potassium uptake of maize straw (ppm/kg) at harvest during spring Season 2023



Where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.4.9 Energy level (kcal/100 gm): The impact of various planting dates and agrochemicals on Energy level (kcal/100 gm) in maize seed at harvest is shown in (Figure 4.4.9.1a, 4.4.9.2b and 4.4.9.3c). In 2022 and 2023, there was a significant difference in Energy level (kcal/100 gm) in maize seed sowing dates and agrochemicals. The observed percentage was calculated by comparing all the mean with optimum sowing in case of different sowing dates. It was estimated by comparing all the standards with the control in agrochemicals. Thus, the percentage pattern in the Energy level (kcal/100 gm) in maize seed was observed at harvest. It was found that the energy level was increased in the treatment where salicylic acid was applied when grown in late conditions, and within the treatment of late sowing, increased energy in the therapy SLA2 by 17.56% as compared to the control SLA0 followed by the treatment where SA and SNP were applied in combination (SLA3). In the case of early sowing, the application of salicylic acid (SEA2) was able to increase the energy level by 34.45% as compared to the control SEA0, followed by the treatment where SA and SNP were applied in combined form (SEA3). It was shown that using agrochemicals does not impact the energy level of maize flour when grown under the optimum time. In that case, the energy was high in the treatment where no agrochemical was applied (SEA0). The result was that the application of salicylic acid alone and the combined application of SA and SNP could mitigate environmental conditions like extreme and cold temperatures during the growth and development of maize by enhancing the energy level of maize flour. The amount of energy released in grains is an essential indicator of the metabolic processes occurring throughout the plant as a whole. These processes include photosynthesis, respiration, and the utilisation of nutrients. This investigation delves deeper into the complex factors that affect the energy levels of crops that were sown either too early or too late compared to the recommended planting schedule. It is essential to have a solid understanding of the variations in energy release to decipher the impact of environmental conditions, the timing of germination, and the subsequent development of vegetative and reproductive structures. When you sow seeds too early, you set off a chain reaction of environmental stresses that significantly impact the energy levels of the emerging seedlings. The impending danger of late-spring frosts becomes more apparent, which can throw off the delicate balance of physiological processes essential for releasing the maximum amount of energy. The disruption of important metabolic processes when an organism is subjected to cold temperatures hurts the effectiveness of the production and utilisation of energy. In the context of early-sown crops, decreased energy levels become an urgent concern because they can lead to reduced plant vigour, impaired nutrient utilisation, and, ultimately, an impact on overall crop productivity. On the other hand, planting seeds later than expected introduces their unique environmental stressors, which intricately influence the energy levels of the crops. The shortened growing season places significant pressure on the plant to hasten the development of its vegetative and reproductive parts. As plants rush through their developmental stages and direct more resources towards their reproductive processes, there is a possibility that their overall energy levels will decrease during this compressed period. Because time moves forward at such a rapid pace, there are limits placed on the ability of plants to maximize the release of their stored energy. This highlights the delicate balance that must be maintained to achieve ideal energy levels despite the varying environmental stressors associated with deviations from the recommended sowing timing. The study of plants' energy levels has revealed a recommended window for sowing seeds. This window of time creates the conditions that are best suited for the growth and development of crops. This timing is in sync with favourable environmental conditions, such as temperature, soil moisture, and the duration of daylight, all of which contribute to the efficiency of metabolic processes and energy release. The synchronizations makes it possible to activate genetic and hormonal methods at the right moment, resulting in consistent and optimal energy freedom. The recommended timing prepares the groundwork for reaching an optimal energy level, critical in determining the crop's overall metabolic efficiency and productivity. A strategic approach investigates the function of growth regulators to mitigate the effect of environmental stress on available energy levels. It is well known that salicylic acid plays a role in plant defence responses; however, it can also be used to modulate energy release processes when adverse conditions are present (Selvaraj et al., 2023; Pinto et al., 2023; Eevera et al., 2023; Rajput et al., 2023; More et al., 2023; Qureshi et al., 2023; Rehman et al., 2023). This tactical application is handy for early-sown crops because it provides a means to protect plants from the potentially damaging effects of late frosts on the development of energy release. Activating stress response genes by salicylic acid increases the plant's ability to withstand environmental stresses, which may lead to a more consistent and efficient release of energy.

In addition, the utilisation of sodium nitroprusside, which acts in the capacity of a nitric oxide donor, constitutes an intervention designed to maximise energy levels. When used appropriately, sodium nitroprusside can affect significant physiological processes like photosynthesis and respiration, affecting the amount of energy released. This application helps establish optimal energy levels, which is especially beneficial for late-sown crops attempting to accelerate reproductive growth despite the constraints of a shorter growing season. The complex application of these growth regulators demonstrates their capacity to modulate the physiological responses of crops when confronted with environmental stressors associated with deviations from the recommended sowing timing. The investigation of the effects of environmental stress on the energy levels of plants provides a comprehensive understanding of the complex interaction between the timing of vegetative and reproductive development, as well as the growth conditions under which they occur. Early-sown crops have to deal with the difficulties of late frosts, which prevent the optimal development of energy release. In contrast, late-sown crops must deal with the challenges of a compressed growing season, which influences metabolic processes and energy release. Based on scientific principles, the recommended timing of sowing emerges as a crucial component in establishing optimal conditions to achieve ideal energy levels. Incorporating growth regulators into scientific approaches, such as salicylic acid and sodium nitroprusside, offers strategic interventions to enhance the resilience of crops by influencing the production of energy release and shaping the crop's overall metabolic efficiency and productivity. This scientific investigation sheds light on the environmental stressors that crops face. It provides a pathway for strategic interventions to navigate these challenges and optimize energy levels for robust crop development. The investigation reveals crops' environmental stressors and provides a pathway (Alugoju and Tencomnao 2023; Younis et al.,2023; Gul et al., 2023).

Figure 4.4.9.1a. Effect of early sowing and agrochemicals treatments on energy level of maize flour (kcal/100gm) at harvest during spring Season 2023

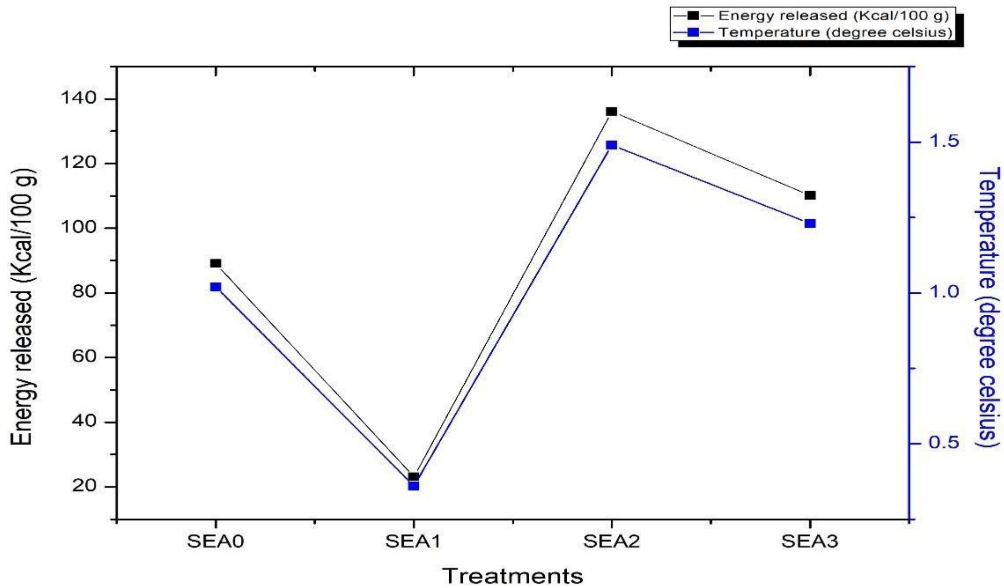


Figure 4.4.9.2b. Effect of optimum sowing and agrochemicals treatments on energy level of maize flour (kcal/100gm) at harvest during spring Season 2023

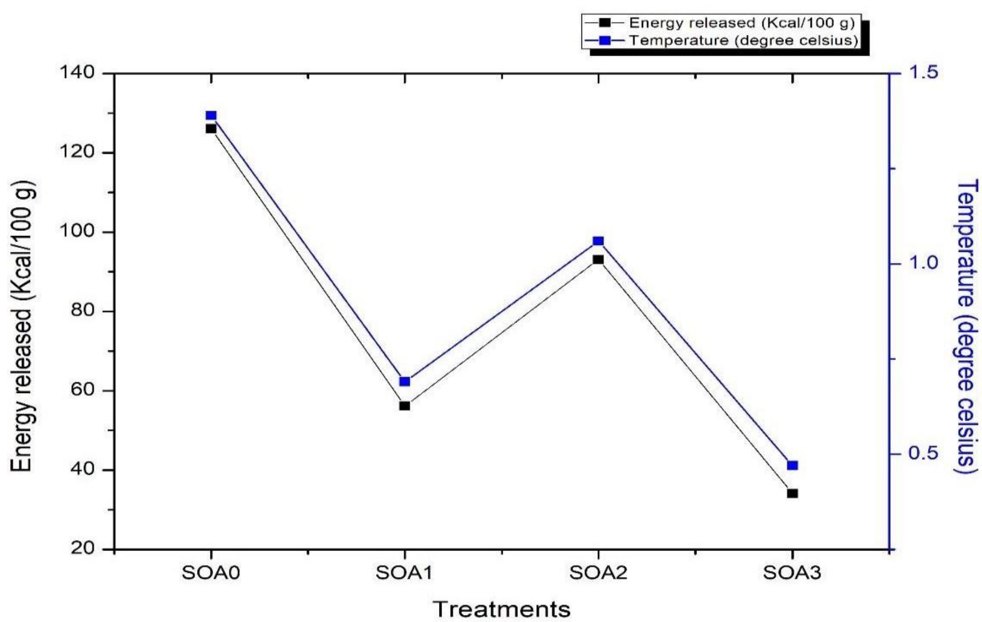
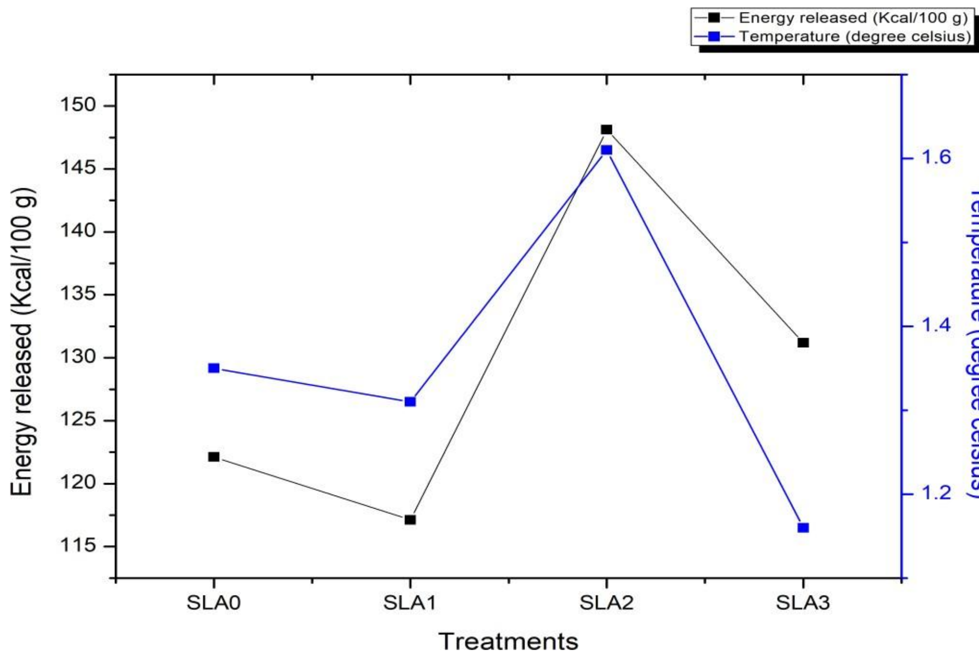


Figure 4.4.9.3c. Effect of late sowing and agrochemicals treatments on energy level of maize flour (kcal/100gm) at harvest during spring Season 2023



Where data is shown as Mean±SD with Duncan at p<0.05; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L)

4.5 Economic analysis

4.5.1 Cost of cultivation (Rs/ha)

The effect of sowing dates and agrochemicals on cost of cultivation in maize at harvest is shown in (Table 4.5.1). In 2022 and 2023 there was significant difference of cost of cultivation in maize sowing dates and agrochemicals. In 2022 early sowing along with the agrochemicals the cost of cultivation in SEA0, SEA1, SEA2 and SEA3 was 45000,46620,47820 and 48000 Rs/ha respectively. In case of optimum sowing along with agrochemicals, the cost of cultivation in S0A0, S0A1, S0A2 and S0A3 was 47200,46820,48650 and 48000 Rs/ha. The interaction of late sowing along with applied agrochemical in cost of cultivation are as followed that SLA0, SlA1, SlA2 and SLA3 was 45900,46800,47900 and 48520 Rs/ha respectively. In 2023 early sowing along with the agrochemicals the cost of cultivation in SEA0, SEA1, SEA2 and SEA3 was 45020,46655,47865 and 48050 Rs/ha respectively. In case of optimum sowing along with agrochemicals the cost of cultivation in S0A0, S0A1, S0A2 and S0A3 was 48700, 46880, 48720 and 48080 Rs/ha. The interaction of late sowing along with applied agrochemical in cost of cultivation are as followed that SLA0, SlA1, SlA2 and SLA3 was 45975, 46870, 47965 and 48575 Rs/ha respectively (More et al., 2023; Qureshi et al., 2023; Rehman et al., 2023).

4.5.2 Gross Return (Rs/ha)

The effect of sowing dates and agrochemicals on Gross Return (Rs/ha) in maize at harvest is shown in (Table 4.5.1). In 2022 and 2023 there was significant difference of Gross Return (Rs/ha) in maize sowing dates and agrochemicals. In 2022 early sowing along with the agrochemicals the Gross Return (Rs/ha) in SEA0, SEA1, SEA2 and SEA3 was 113142,123606,139738 and 122952 Rs/ha respectively. In case of optimum sowing along with agrochemicals the Gross Return (Rs/ha) in S0A0, S0A1, S0A2 and S0A3 was 156306,149330,122734 and 137776 Rs/ha. The interaction of late sowing along with applied agrochemical in Gross Return (Rs/ha) are as followed that SLA0, SlA1, SlA2 and SLA3 was 121426, 151292,161974 and 140392 Rs/ha respectively. In 2023 early sowing along with the agrochemicals the Gross Return (Rs/ha) in SEA0, SEA1, SEA2 and SEA3 was 175708,191840, 198598 and 181812 Rs/ha respectively. In case of optimum sowing along with agrochemicals the Gross Return (Rs/ha) in S0A0, S0A1, S0A2 and S0A3 was 215166,208190,181594 and 215166 Rs/ha. The interaction of late sowing along with applied agrochemical in Gross Return (Rs/ha) are as followed that SLA0, SlA1, SlA2 and SLA3 was 180286, 210152,215602 and 199252 Rs/ha respectively (Laribi et al., 2023; Yadav and Singh 2023; Azizkhani et al., 2023).

4.5.3 Net Return (Rs/ha)

The effect of sowing dates and agrochemicals on Net Return (Rs/ha) in maize at harvest is shown in (Table 4.5.1). In 2022 and 2023 there was significant difference of Net Return (Rs/ha) in maize sowing dates and agrochemicals. In 2022 early sowing along with the agrochemicals the Net Return (Rs/ha) in SEA0, SEA1, SEA2 and SEA3 was 68142,76986, 9191 and 74952 Rs/ha respectively. In case of optimum sowing along with agrochemicals the Net Return (Rs/ha) in S0A0, S0A1, S0A2 and S0A3 was 1091106,102510,74084 and 89776 Rs/ha. The interaction of late sowing along with applied agrochemical in Net Return (Rs/ha) are as followed that SLA0, SlA1, SlA2 and SLA3 was 75526,104492,114074 and 91872 Rs/ha respectively. In 2023 early sowing along with the agrochemicals the Net Return (Rs/ha) in SEA0, SEA1, SEA2 and SEA3 was 130688,145185, 150733 and 133762 Rs/ha respectively. In case of optimum sowing along with agrochemicals the Net Return (Rs/ha) in S0A0, S0A1, S0A2 and S0A3 was 166466,161310,132874 and 148556 Rs/ha. The interaction of late sowing along with applied agrochemical in Net Return (Rs/ha) are as followed that SLA0, SlA1, SlA2 and SLA3 was 134311,163282,167637 and 150677 Rs/ha respectively.

4.5.4 B:C Ratio

The influence of planting dates as well as agrochemicals on B:C Ratio in maize at harvest is shown in (Table 4.5.1). In 2022 and 2023 there was significant difference of B:C Ratio in maize sowing dates and agrochemicals. In 2022 early sowing along with the agrochemicals the B:C Ratio in SEA0, SEA1, SEA2 and SEA3 was 1.51,1.65, 1.92 and 1.56. In case of optimum sowing along with agrochemicals the B:C Ratio in S0A0, S0A1, S0A2 and S0A3 was 2.31,2.19,1.52 and 1.87. The interaction of late sowing along with applied agrochemical in B:C Ratio are as followed that SLA0, SlA1, SlA2 and SLA3 was 1.65,2.23,2.38 and 1.89 respectively. In 2023 early sowing along with the agrochemicals the B:C Ratio in SEA0, SEA1, SEA2 and SEA3 was 2.90,3.11,3.15 and 2.78 respectively. In case of optimum sowing along with agrochemicals the B:C Ratio in S0A0, S0A1, S0A2 and S0A3 was3.42,3.44, 2.73 and 3.09. The interaction of late sowing along with applied agrochemical in B:C Ratio are as followed that SLA0, SlA1, SlA2 and SLA3 was 2.92, 3.48, 3.49 and 3.10 respectively where data is shown as Mean±SD with Duncan at $p<0.05$; DAS: days after sowing; Main Plot- SE- Early Sowing, S0- Optimum sowing, SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L).

Table 4.5.1.1 Interaction effect of sowing dates and agrochemicals treatments on economic analysis of Maize during Spring Season 2022 and 2023

Treatments	2022				2023			
	Cost of cultivation (Rs/ha)	Gross Return (Rs/ha)	Net return (Rs/ha)	B:C Ratio	Cost of cultivation (Rs/ha)	Gross Return (Rs/ha)	Net return (Rs/ha)	B:C Ratio
SEA0	45000	113142	68142	1.51	45020	175708	130688	2.90
SEA1	46620	123606	76986	1.65	46655	191840	145185	3.11
SEA2	47820	139738	91918	1.92	47865	198598	150733	3.15
SEA3	48000	122952	74952	1.56	48050	181812	133762	2.78
S0A0	47200	156306	109106	2.31	48700	215166	166466	3.42
S0A1	46820	149330	102510	2.19	46880	208190	161310	3.44
S0A2	48650	122734	74084	1.52	48720	181594	132874	2.73
S0A3	48000	137776	89776	1.87	48080	196636	148556	3.09
SLA0	45900	121426	75526	1.65	45975	180286	134311	2.92
SLA1	46800	151292	104492	2.23	46870	210152	163282	3.48
SLA2	47900	161974	114074	2.38	47965	215602	167637	3.49
SLA3	48520	140392	91872	1.89	48575	199252	150677	3.10

CHAPTER-V

SUMMARY AND CONCLUSION

The agricultural sector is seriously impacted by climate change, leading to potential risks to food security. In terms of global food production, maize ranks third. As a result, crop production and food security depend critically on assessing the effects of climate change and developing measures to adapt maize. Regarding adaptability, changing planting dates and using different agrochemicals are more effective than other management. Crop models are part of a global decision support system to help farmers maximize yields despite unpredictable weather patterns. To mitigate yield loss and protect the ecosystem, it is essential to use efficient maize-sowing practices in the field. This entails identifying the most favorable sowing dates that maximize yield while ensuring the crop's productivity and the integrity of the surrounding ecosystem remain intact. The objectives of my study: 1. To study temporal dynamics and agrochemicals on hybrid maize growth, yield, as well as quality. 2. To study the impact of temporal dynamics and agrochemicals on nutrient uptake of hybrid maize. 3. To study the evaluation of salicylic acid and SNP on the biochemical behavior of hybrid maize. 4. To study the impact of different treatments on the economic feasibility of the hybrid maize. This experiment was carried out to mitigate the different climatic conditions by exogenous application of salicylic acid (SA) and sodium nitroprusside (SNP) on morphological, biochemicals, yield and quality parameters in maize under different sowing dates. An experiment was carried out at Punjab's Lovely Professional University's School of Agriculture. India, during the spring of 2022. The experiment dealt with various maize crops, PMH-10, sourced from the Punjab Agricultural University (PAU), Punjab. The research was carried out in the open air. The experimental setup was laid out in a split-plot design. According to the findings, high-temperature tolerance was successfully induced during the reproductive period by foliar application of growth-promoting chemicals and other growing climatic conditions of maize in early and late sowings when controlled by improving the morpho-physiological, biochemicals, yield attributing, and quality parameters of maize. Data were collected on days 30, 60, along with 90 DAS, at various growth intervals. and at harvest on various parameters like morphological, biochemicals, yield attributing and quality parameters of maize in 2022 and 2023. The treatment details are SL- Late sowing; Subplot- A0- Control, A1-Sodium nitroprusside (250 µM/L), A2-Salicylic acid (150mg/L), A3- Sodium nitroprusside (250 µM/L) + Salicylic acid (150mg/L).

- In the case of different sowing dates, the percentage of days to 50% of germination was decreased in the case of early sowing (S0) by 27.28 % when compared with optimum sowing, but in the case of late sowing (SL), the days to 50 % of germination was increased by 18.34% as compared to optimum sowing (SE). The late sowing (SL) shows a better result by decreasing the days for germination as compared to optimum sowing (S0).
- The application of salicylic acid (A2) increased the percentage of plant height by 13.82 compared to the control at 30 DAS. Similarly, 60 DAS, the plant height percentage was increased by 3.82 %, 2.92%, and 3.27 in A1, A2, and A3, respectively, compared to the control.
- The application of agrochemicals also showed better results by increasing the number of leaves; at 30 DAS, the A1 decreased the percentage by 7.67% as the A2 and A3 increased the rate of the number of leaves per plant by 7.945 and 3.41%, respectively, as compared to the control A0. At 60 DAS, agrochemicals (A3) combined application showed a better result by increasing the percentage by 1.77 compared to the A1 and A2.
- The different sowing dates, the early sowing (SE) and late sowing (SL) decreased the percentage of internodal length by 7.27% and 3.49%, respectively, as compared to the optimum sowing (S0) at 30 DAS. At 60 DAS, the early sowing (SE) was able to increase the percentage by 3.08%, and late sowing (SL) decreased the rate by 9.47%, respectively, when compared with optimum sowing (S0).
- It was recorded that the combined application of sodium nitroprusside and salicylic acid among agrochemicals showed a better result by increasing the percentage of stem girth by 35.78% compared to the control (A0) at 30 DAS. AT 60 DAS, the A1 showed the highest percentage, i.e. 9.13%, among all other applied agrochemicals. But at 90 DAS, the rate significantly increased in the A2 by 8.26%, followed by A1 and A3,

i.e. 6.27% and 2.30%, respectively, compared to A0.

- It was also recorded that A3 showed a better result among applied agrochemicals, which significantly increased the percentage of leaf area by 11.09% and A2 by 2.26%, respectively, when compared with A0 at 30 DAS. At 60 DAS, A1 had the highest rate, i.e., 37.07%, followed by A3 and A2 by 20.92% and 19.02%, respectively, compared to A0.
- It was recorded that early (SE) and late sowing decreased the days to 50% tasseling by 20.19 % and 11.06 %, respectively, compared to the optimum sowing. It means that late sowing (SL) took fewer days for the 50 % tasseling. In the case of applied agrochemicals, the combined application of sodium nitroprusside and salicylic acid (A3) decreased the percentage by 2.81% compared to other used agrochemicals.
- In the case of applied agrochemicals, A1 showed a better result by decreasing the percentage of cob placement height by 24.42%, followed by A3 and A2 by 22.58% and 15.70%, respectively.
- It was recorded that early sowing (SE) and late sowing (SL) increased the percentage of plant population by 3.82% and 5.27%, respectively, when compared to the optimum sowing (S0). In the case of applied agrochemicals, salicylic acid (A2) shows a better result by increasing the percentage by 14.37%, followed by the A1 and A3, i.e.,4.08% and 3.78%, respectively, as compared to the control (A0).
- The salicylic acid (A2) had the highest percentage of crop growth rate, i.e. 6.18%, 35.63%, and 12.8 at 30, 60, and 90 DAS, respectively, compared to the control (A0). The combined application showed a better result (A3) and increased the percentage by 2.12%, 16.78%, and 8.65%, respectively, compared to the control (A0), and similar trends were followed at 90 DAS.
- Salicylic acid (A2) application in applied agrochemicals shows better results by increasing the percentage of relative growth rate by 10.25% and 59.09% at 60 and 90 DAS, respectively, compared to control (A0).
- Salicylic acid (A2) application showed a better result by increasing the percentage of net assimilation rate by 8.79%, followed by A3 and A1, respectively.
- The application of salicylic acid (A2) also showed a better result by increasing the percentage of leaf area index by 2.73%, 26.01 and 0.45% at 30, 60 and 90 DAS,

respectively, compared to the control (A0).

- It was found that in applied agrochemicals, the application of salicylic acids (A2) showed better results by increasing the percentage of dry accumulation by 4.99%, 10.14%, and 1.34% at 30, 60, and 90 DAS, respectively, compared to control (A0).
- The application of salicylic acid (A2) showed an increase of chlorophyll index 11.22%, followed by A3 and A1 by 9.41% and 3.69%, respectively, compared to the control (A0).
- Among the applied agrochemicals, A1 increased the percentage of total soluble sugar by 13.32%, A2 increased by 4.66%, and A3 increased the rate by 1.13% compared to control (A0).
- Among the applied agrochemicals, A1 increased the percentage of total soluble protein by 15.67%, A2 by 97.06%, and A3 increased the rate by 12.77% compared to control (A0).
- Among the applied agrochemicals, A1 increased the percentage of total reducing sugar by 37.42%, A2 increased by 66.07%, and A3 increased the percentage by 26.92% compared to control (A0).
- Among the applied agrochemicals, A1 reduced the rate of lipid peroxidation by 22.65%, A2 decreased by 37.98%, and A3 decreased the percentage by 54.88% compared to control (A0).
- The percentage of catalase decreased in A1 and increased in A2 and A3 by 1.75%, 1.40%, and 7.86%, respectively, compared to the control (A0).
- Among the applied agrochemicals, A1 increased the percentage of total starch by 13.33%, A2 increased by 4.67%, and A3 increased the percentage by 1.14% compared to control (A0).
- The percentage of total amylopectin increased in A1, whereas it increased in A2 and A3 by 27.22%, 44.41%, and 23.41%, respectively, compared to the control (A0).
- Among the applied agrochemicals, A1 increased the percentage of membrane stability index by 13.36%, A2 increased by 40.12%, and A3 increased by 22.00% compared to control (A0).
- Among the applied agrochemicals, A1 decreased the percentage of membrane injury index by 17.32%, A2 by 14.64%, and A3 decreased the percentage by 6.27% when

compared to the control (A0).

- The foliar application of salicylic acid (A2) showed a better result by increasing number of cobs/plant by 21.93% compared to the control (A0).
- Among the agrochemicals, the application of sodium nitroprusside (A1) increased the percentage of cob length by 4.33% compared to the control (A0).
- The salicylic acid (A2) application showed a better result by increasing the number of kernel rows/cob the rate by 11.14% compared to the control (A0).
- The application of salicylic acid (A2) showed a better result by increasing the rate of the number of kernel/cobs by 25.89% compared to the control (A0).
- The application of salicylic acid (A2) showed a better result by increasing the percentage of kernel weight/cob by 10.22% compared to the control (A0).
- The application of salicylic acid (A2) showed a better result by increasing the cob's weight rate by 9.16% compared to the control (A0).
- The application of salicylic acid (A2) showed a better result by increasing the cob's weight rate by 3.27% compared to the control (A0).
- The application of salicylic acid (A2) showed a better result by increasing the percentage of cob diameter by 4.41% compared to the control (A0).
- The application of salicylic acid (A2) showed a better result by increasing the rate of stover yield by 34.65% compared to the control (A0).
- The application of salicylic acid (A2) showed a better result by increasing the rate of harvesting index by 7.58% compared to the control (A0).
- The application of salicylic acid (A2) showed a better result, increasing the rate of test weight by 3.96% compared to the control (A0).
- The application of salicylic acid (A2) showed a better result, increasing the rate of total starch by 43.15% compared to the control (A0).
- The application of salicylic acid (A2) showed a better result by increasing the nitrogen uptake rate by 7.42% compared to the control (A0).
- The application of salicylic acid (A2) showed a better result by increasing the rate of phosphorous uptake by 23.38% compared to the control (A0).
- The application of salicylic acid (A2) showed a better result by increasing the rate of potassium uptake by 15.82% compared to the control (A0).

- The benefit cost ratio was found high in application of salicylic acid in late sowing by 2.38 and 3.49 in 2022 and 2023 respectively.

The following conclusion has been drawn from the present investigation: which may be beneficial for farmers to grow maize in different environmental conditions, which will change due to climate change in coming years throughout the world and may affect crop production drastically. So, this farmer may go for the growing maize under different temporal dynamics along with the other applied agrochemicals.

From the results it was indicated that alteration in sowing dates as early and late changes the growing climatic conditions for the maize which directly effects the morphophysiological and yield attributers of maize in different ways as in cold and hot climatic conditions as compared to the optimum sowing conditions. It was concluded that among the main factors considering different sowing, late sowing (SL) showed a better result than early sowing (SE). Similarly, in the case of an element where different agrochemicals were applied, the application of salicylic acid showed a better result by improving the growth and development of maize under other sowing dates. The interaction of sowing dates and agrochemicals also showed a better result. In that case, the late sowing and salicylic acid (SLA2) were best over the growth along with development of maize in the years 2022 and 2023. The late sowing with application of salicylic acids shows better result by increasing the nutrient uptake by the maize as compared to the early sowing. Both applied agrochemicals salicylic acid and sodium nitroprusside shows the better result by improving the different biochemical activities in maize leaves which directly involved in the different metabolic activities of plants when grown under the different temporal dynamics. The late sown maize with application of salicylic acid showed the better result by increasing the benefit cost ratio which will helps the farmer for the economic point of view.

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