Impact of Zinc and Boron Foliar Application on Growth and Yield in Primed Mung Bean (*Vigna radiata* L.)

Thesis Submitted for the Award of the Degree of

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Agronomy

By

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2025

DECLARATION

I, hereby declared that the presented work in the thesis entitled **“Impact of Zinc and Boron Foliar Application on Growth and Yield in Primed Mung Bean (*Vigna radiata* L.)”** in fulfilment of degree of **Doctor of Philosophy (Ph. D.)** is outcome of research work carried out by me under the supervision of **Dr. Hina Upadhyay** and **Dr. Prasann Kumar**, working as Associate Professor and 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 other 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 **"Impact of Zinc and Boron Foliar Application on Growth and Yield in Primed Mung Bean (*Vigna radiata* L.)""** submitted in the fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Department of Agronomy of the School of Agriculture is a research work is carried out by **Lalit Saini (12021200)** is a bonafide record of his 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

Climate change and variation pose major challenges to agricultural yield. In many places, agricultural yield and output are hindered by the effects of global warming. Many environmental limitations, including heat, cold, salt, drought and heavy metals, can have impact on plants growth. In the present research, it was suggested that spraying micronutrients like zinc (Zn) and boron (B) and examining their impact on growth, physiological characteristics, flowering, seed production, and yield potential of primed mung bean treated with phytohormones (SA and GA_3). Phytohormones are also essential chemical messengers that enable plants to survive and thrive in the face of a variety of stressors. Consequently, phytohormone seed priming help the plant to withstand with adverse environmental conditions. Plant growth hormones play a vital role in several stages of plant development, including seed germination, stem elongation, beginning of blooming, and the development of fruits and flowers. This experiment demonstrates that the simultaneous use of Zn and B as micronutrients, along with gibberellin and salicylic acid, resulted in a favourable response in morphophysiological parameters of mung bean plants. This included an increase in height of the plant, branches per plant, leaves per plant, nodules per plant, and leaf area index (LAI). Additionally, the growth parameters such as 50% flowering days, fresh and dry weight, CGR, NAR and RGR were positively influenced at at various phases of growth. These improvements directly impact the crop production. Similarly, the application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage in chlorophyll a by 43 and 34.3% at 30-DAS and 60-DAS as compared to the control (T0). In *Kharif* 2022 and 2023, combined foliar micronutrient application with SA priming in treatment (T10) increased chlorophyll content by 35.6 and 19.6% at 30-DAS and 60-DAS when compared to the control (T0). The combined application of salicylic as phytohormones priming sowing showed numerous plant physiological activities, including the response to adverse environmental conditions, and imparts plant defense inducing systemic acquired resistance. The application of SA decreased the content of membrane injury index (MII). The application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage in total soluble protein by 35.6 and 41% at 30-DAS and 60-DAS as compared to the control (T0). Combined B and Zn application in primed mung bean with gibberellins and salicylic acid showed a positive response by improving the yield attributing characters which directly influence the yield of the mung bean like pods plants^{-1}, number of seeds/pod, length of pod (measured in centimeters), seed yield (q/ha) and harvesting index. The application of phytohormone priming and foliar application with Zn + B (T9) in *Summer* 2022 enhanced the percentage of test weight by 10.4% when compared to control and in *Summer* 2023 in (T9) it enhanced the percentage of test weight by 10.6% when compared to control (T0). In *Summer* and *Kharif* 2022-2023, *Summer* 2022 Treatment T9 (gibberellic acid seed priming combined with zinc and boron foliar sprays) demonstrated exceptional results, significantly boosting germination rates, plant height, fresh and dry biomass, leaf and branch counts, root length, nodule formation, leaf area index, crop growth rate, chlorophyll levels, soluble sugars, protein content, membrane stability, seed yield, and economic returns compared to the control (T0).

Keywords: Abiotic stress, Climate change, Micronutrients, Mung bean, Priming, Zero hunger, sustainability

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LIST OF ABBREVIATIONS	SYMBOLS USED
;	Semicolon
%	Per cent
:	Colon
GA_3	Gibberellic Acid
^0C	Degree Celsius
SA	Salicylic Acid
Z	Zinc
B	Boron
Chl a	Chlorophyll a
Chl b	Chlorophyll b
Cm^2	Square Centimeter
Cm	Centimetre
CO_2	Carbon dioxide
RBD	Randomized Block Design
Conc.	Concentration
DAS	Days after sowing
EC	Electrical Conductivity
EDTA	Ethylenediaminetetraacetic acid
et al.,	Co-worker

FW	Fresh Weight
DW	Dry Weight
Q	Quintal
Ha	Hectare
G	Gram
g cm^{-3}	Gram per cubic centimetre
HCl	Hydrochloric Acid
H_2SO_4	Sulphuric Acid
H_2O_2	Hydrogen Peroxide
kg ha^{-1}	Kilogram per hectare
lakh ha	Lakh hectare
lakh tons	Lakh tons
M	Molar
MDA	Malondialdehyde
Mg	Milligram
mg kg^{-1}	Milligram per kilogram
ml	Milliliter
mM	Millimolar
N	Normal
Nm	Nano Meter

POD	Peroxidase
ppm	Parts Per Million
R	Replication
rpm	Rotation Per Minute
RWC	Relative Water Content
SOD	Super Oxide Dismutase
T	Treatment
TBA	Thiobarbituric Acid
TCA	Trichloroacetic Acid
UV	Ultra Violet
w/v	weight by volume
MSI	Membrane Stability Index
MII	Membrane Injury Index
CGR	Crop Growth Rate
RGR	Relative Growth Rate
NAR	Net Assimilation Rate
TSS	Total Soluble Sugar
TSP	Total Soluble Protein
DMRT	Duncan’s Multiple Range Test

CHAPTER I

INTRODUCTION

Following pigeon pea and chickpea, mung bean (*Vigna radiata* L.) is India's third most significant pulse legume. Mung bean (*Vigna radiata* L.), alternatively referred to as golden gram or green gram, is a leguminous vegetable widely cultivated across various agroecological zones across the globe. Its significant protein content, which aids in preventing protein malnutrition among approximately 43% of the vegetarian population in India, is a global recognition of its nutritional value. With its brief growth cycle and adaptability, this food item is not just a staple but a lifeline for many. It is the second-most essential food source after cereal crops, underscoring its nutritional significance. In Asia, moong legumes are a vital pulse crop. The domestication of the mung bean is believed to have begun on the Indian subcontinent around 1500 BC. Although primarily cultivated in East, Southeast, and South Asia, it has also been introduced to portions of Africa and the United States of America, a testament to its global recognition and adaptability (Varma et al., 2023). Most mung bean production (90%) occurs in Asia, with India being the leading producer, accounting for over 50% of global output. However, India uses nearly all of its production. Mung bean, an ancient Asian legume, is indispensable for its nutritional value. It is incorporated into various foodstuffs, including "Dal" and whole cereals. Curry or other dishes in South India are prepared with sprouted green gram (Nair et al., 2020).

Pulses, an exceptional source of dietary proteins, help meet the nutritional needs of a population that is expanding at an alarming rate. However, pulse production is significantly inadequate compared to the needs of our nation's growing population, which has become an alarming issue. This deficiency in the human diet results in numerous problems, including stunted development and growth, especially in developing children. In India, the protein content of the average person's diet is significantly below the ICMR's minimum recommendation of 80 g per day. (Gupta et al., 2022). The urgency to increase production is apparent, as it is grossly inadequate compared to demand. To meet national demand, there is a need to improve both the area and the production of crop seeds. Patients prefer this particular variety due to its reputed ease of digestion. It comprises 3–4.5% fibres, 4–5% ash, and 3% lipids. Moong beans contain 25 percent protein, 59.9 percent carbohydrates, and a significant amount of lysine (450.2 mg/kg) and tryptophan (60.2 mg/kg). Sprouting it also yields a notable quantity of riboflavin (0.22 mg 100 g-1), minerals (3.82 g/100 g) ascorbic acid and calcium (70 mg/ 100g) (Krishan et al., 2022). Sprouts of beans are an excellent source of vitamin C (8 mg, 100 g). As per the FAO recommendation, an individual's daily pulse consumption should be 80 g; however, the current daily intake is 7.92 g (Hosen 2021).

Green gram seeds produce extraordinary ascorbic acid (Vitamin C) during germination. The mung bean cultivation area in India grew from 4.50 million hectares in 2018 to 4.60 million hectares in 2019, 4.80 million hectares in 2020, 5.00 million hectares in 2021, and 5.50 million hectares in 2022, per Ministry of Agriculture, IIPR, and Statista. Production increased from 2.50 million tonnes in 2018 to 2.10 million tonnes in 2019, 2.60 million tonnes in 2020, 2.80 million tonnes in 2021, and 3.17 million tonnes in 2022. Productivity varied, starting at 556 kg/ha in 2018, dropping to 457 kg/ha in 2019, rising to 542 kg/ha in 2020, reaching 560 kg/ha in 2021, and peaking at 576 kg/ha in 2022. These trends reflect steady growth with a notable dip in 2019, likely due to weather or market factors (IIPR 2023). Key states in India cultivating mung bean include Bihar, Odisha, Maharashtra, Andhra Pradesh, Madhya Pradesh, Gujarat, and Rajasthan. Orissa leads in both area and productivity, followed by Maharashtra and Andhra Pradesh. Odisha spans 8.36 lakh hectares with an average yield of 434 kg/ha, while Madhya Pradesh cultivates 2.97 lakh hectares, producing 2.20 lakh metric tonnes (Hazra et al., 2023). Mung bean cultivation in Punjab, as reported by Punjab Agricultural University, shows stable area coverage and fluctuating production from 2019 to 2023. In 2019, the area was 0.018 million hectares, producing 0.013 million tonnes with a productivity of 722 kg/ha. For 2020, the area remained 0.018 million hectares, with production at 0.014 million tonnes and productivity at 778 kg/ha. In 2021, the area was 0.017 million hectares, yielding 0.012 million tonnes at 706 kg/ha, while 2022 saw 0.018 million hectares, 0.013 million tonnes, and 722 kg/ha. By 2023, the area was 0.018 million hectares, with production at 0.014 million tonnes and productivity at 778 kg/ha (PAU 2025). To obtain dry seeds, the beans are harvested when they are still young and delicate, whereas, for culinary purposes, they are harvested when they are tender. Moong beans are critical in crop rotations because they incorporate nitrogen into the soil, increasing fertility. The crop substantially contributes to the global agricultural sector by providing a multipurpose and nourishing food source and facilitating sustainable farming methods via its ability to fix nitrogen. As a crop with a brief duration, it is compatible with numerous intensive crop rotations. Green gram is suitable for use as cattle fodder. Green plants are uprooted or cut from the ground level, then chopped into tiny pieces and fed to the cattle, following the harvesting of the pods. Soaking the seed's husk in water will result in its use as cattle fodder. The crop is classified as self-pollinating (Sharma et al., 2021). It is cultivated during the *Kharif* and *Summer* seasons in North India and the south. When the *rabi* season approaches, this crop can be grown in India. Green gram thrives in regions with an average annual precipitation of 60 to 75 centimetres. It demands a highly humid climate. Green gram is widely recognised as the most drought-tolerant pulse crop, among all others. Thus, it can be grown effectively in any unfavourable environment, especially in regions prone to drought during the *Kharif* season. Green gram can thrive in diverse well-draining soil types, including sandy loam and black cotton soils. Saline and alkaline soils are not conducive to the cultivation of green grains. The sensitivity of green gram to waterlogging conditions has been noted (Thind 2022).

Generally, the crop cultivation cycle commences during the warm seasons with the direct sowing of seedlings in the field. Annual moong bean vines are distinguished by their fuzzy brown pods and yellow blooms. *Vigna radiata* comprises three subdivisions: one is cultivated (*Vigna radiata* subsp. *radiata*), and the other two are found in the wild. The mung bean plant possesses a robust root system. Numerous slender lateral roots are adorned with root nodules. Stems are densely branched and, at times, twine at the extremities. Mature stems are greyish-yellow or brown, whereas young stems are purple or green; the crop is self-pollinating. Typically, 30 to 50 fruits per plant are elongated cylindrical or flat cylindrical capsules. The stages at which the tiny, green seeds contained in the pods are harvested vary according to their intended use. (Krishna et al., 2022). The pods are 5–10 centimetres in length and 0.40–0.60 cm in width, containing 12–14 septum-separated seeds. Every pulse crop plant functions as a miniature nitrogen fertiliser in nature, fulfilling its nutritional needs while providing advantages to subsequent crops. In addition, legumes serve the crucial purpose of nitrogen fixation in the atmosphere (30–40 kg N/ha), which enhances nitrogen contents and improves soil health by manipulating chemical or the physical properties as well as the biological properties. In addition to their nutritional value and capacity to fix nitrogen, pulses improve the soil's physical or chemical characteristics as well as biological characteristics, contributing significantly to intensive agriculture's sustainability (Singh *et al.*, 2022).

SML 1827 is a *Summer* variety of mung bean with medium stature and an erect and determinate nature. It grows legumes in clusters and reaches maturity simultaneously (approximately 62 days). Each capsule is composed of roughly ten seeds. It possesses yellow mosaic disease resistance. Medium in size and gleaming green, the grains have excellent culinary qualities. Five quintals are produced on average per acre.

ML 1808 is a medium-statured, upright 71 cm *Kharif*-season mung bean variety specimen. Proliferate formation of pods is observed, with pod^{-1} housing 11–12 seeds. It exhibits resistance to disorders such as bacterial leaf spot, Cercospora leaf spot, and mung bean yellow mosaic virus. The grains are bright green, moderately robust, and of high culinary quality. On average, a quintal of cereal is produced per acre.

The plant *Vigna radiata* grows prostrate and generates pod clusters, enclosing the highly valued seeds. The optimal time to harvest can differ depending on the intended use, which may be for raw consumption, sprouting, or dried seeds. In the case of fresh beans, the pods are harvested when young and swollen, whereas, for dried seeds, one must wait until the pods reach maturity and dry naturally on the plant. Post-harvest processing may consist of cleaning, drying, and threshing to prepare the legumes for storage or consumption (Revaprasadu *et al*., 2021). Major challenges in pulse cultivation include seed germination, seed emergence, plant mortality, and crop establishment. Each of these issues is linked to a reduction in pulse productivity. Priming with seeds is a more effective method for increasing seed germination, seedling emergence, and plant stand, which contributes to the self-sufficiency of pulse production and, consequently, the availability of a balanced diet for India's impoverished population (Farooq *et al*., 2019).

Seed priming is one of the pre-sowing seed treatments that has demonstrated efficacy for legumes. Seed priming involves subjecting seeds to a controlled period of soaking in water (or a saline solution) to induce partial germination. Subsequently, the seeds are dried to their initial moisture content just before the emergence of radicles (Marthandan et al., 2020). Numerous metabolic processes that are involved in the initial phases of germination are stimulated by priming. Additionally, primed seeds emerge more uniformly than unprimed seeds, resulting in a more uniform stand of vegetation. Mung bean yield is significantly hampered by inadequate stand establishment. The current objective in agriculture is to improve the emergence and establishment of crop stands, specifically for cultivars that possess limited physical and genetic vitality. A minimal quantity of nutrients is necessary for optimal plant development and yield enhancement; their deficiency can disrupt plants' physiological and metabolic processes. Seed priming enhance the emergence and growth of plants, leading to a subsequent increase in yield. Protective substances mitigate DNA damage and apical meristem cell mortality, including seed hormone priming and antioxidants (Hossain et al., 2022). In harsh climatic conditions, effective germination and plant development are enhanced by this method of priming of seeds. Furthermore, seed priming facilitates germination % (percentage) of seeds in adverse environmental conditions by decreasing emergence time by fifty per cent and the average time to germination (Qamar et al., 2022). Seed priming ensures germination uniformity and accelerates numerous metabolic processes that are essential for proper germination. The activity of enzymes directly participated in the metabolism of food contained in seeds is enhanced through seed priming.

Gibberellin

GA_3 represents gibberellin, which is also referred to as gibberellic acid. Gibberellin generally promotes cell division and elongation by disrupting dormancy with gibberellic acid. According to Castro et al. (2022), the yield and morphological attributes of legume crops, including soybean and moong bean, can be altered by applying GA_3. It functions as a plant growth regulator, which is increasingly crucial in the agricultural sector to improve output. Gibberellin's seed priming may significantly impact numerous aspects of plant life, such as leaf expansion, phloem loading, minerals and water absorption, translocation of assimilates in different parts of plants, and harvest index (Bhattacharya et al., 2021).

Salicylic Acid

Salicylic acid is classified as a hormone-like compound that exerts significant influence over different physiological processes and safeguards plants against stresses having biotic and abiotic. In addition to facilitating stomatal closure, ion uptake, transpiration, and stress tolerance, it also regulates these physiological processes in plants (Sabagh et al., 2021). Additionally, it might have a significant impact on controlling their development and output. Additionally, hormone priming of seeds mitigates the detrimental effects of numerous environmental stresses. A modest concentration of salicylic acid used to prime seeds will accelerate germination and promote the development of seedlings. Consequently, the susceptibility of the planted seedlings to soil-borne pests and diseases will be diminished (Mahmood et al., 2020).

Current Micronutrient Status in Indian Soil

The proportion of soils in India that lack zinc is 48.1%, iron deficiency affects 11.2%, copper deficiency affects 7%, and manganese deficiency affects 5.1%. In certain regions, deficiencies in boron and molybdenum have also been documented, in addition to the micronutrient deficiencies discussed (Malik et al., 2023). Although the majority of soils in India contain sufficient amounts of total micronutrients (zinc, iron, manganese, and copper), the concentrations of micronutrients in soil solutions are often inadequate to meet the nutritional needs of crops grown in those soils. Plants in Indian soil obtain zinc in the form of DTPA (diethylenetriamine pentaacetate) constituents, which account for less than 1% of the overall zinc content. The DTPA constituents of zinc in soil samples from India vary in concentration from 0.09 to 20.4 mg/kg (Setia et al., 2021). Haryana has the highest zinc deficiency among the states of India, followed by Madhya Pradesh and others. Zinc-containing fertilisers, specifically zinc sulphate, can potentially enhance crops' productivity in densely populated Punjab and Haryana regions by mitigating zinc deficiency (Shukla et al., 2021). Boron is an additional micronutrient that inhibits plant growth in the event of deficiency. Generally, boron deficiency initially manifests in the nascent vegetative components of the plant. If an established portion of the plant dies and ceases to grow, boron is absent from the soil. Boron content in Indian soil varies between 1.5 and 200.5 mg/kg, with planted plants having access to a negligible amount (3.5 to 5.5%). Various factors, including soil texture, the proportion and composition of silt and minerals, and the presence or absence of organic matter, influence boron availability in soil. Boron-based fertilizers comprise 17.47% of the nutrient content and enhance plant development and growth (Kohli *et al.,* 2023).

Within the dynamic realm of agricultural research, pursuing novel and environmentally conscious methodologies to augment crop yields has emerged as a critical concern. Given the simultaneous expansion of global populations and the unpredictable impacts of climate change on conventional farming systems, there is an increasing demand for agricultural techniques that are both resilient and resource-efficient. The significance of micronutrients in plant development and growth has garnered considerable attention. Micronutrients promote optimal development and wholesome growth in human beings and field vegetation (Zewide et al., 2021). Zinc (Zn) and boron (B) are micronutrients of the utmost importance, as they are fundamental to numerous biochemical and physiological processes essential for plant optimal development. Foliar application, an approach that entails the direct application of nutrients onto the foliage of plants, has surfaced as a viable and focused method of augmenting vital elements required for the improvement of plants. This approach facilitates the swift assimilation of nutrients, circumvents potential limitations imposed by the soil, and provides an immediate solution to nutrient deficiencies. Considerable interest has been devoted to the potential of applying B and Zn foliarly to augment mung bean growth and yield (Dhaliwal et al., 2022).

It has been documented that zinc can increase cereal yield. Zinc deficiency can be attributed to using high-purity chemical fertilizers and intensive cropping systems, which favour high-yielding cultivars. The prevalence of zinc deficiency has increased over the past decade (Younas et al., 2023). Plants and animals require zinc to maintain a healthy metabolic system in minute amounts. It metabolizes carbohydrates, proteins, lipids, and nucleic acids and is essential for enzyme activation. Zinc sulphate application enhance the production of seeds, number of clusters per plant, and vegetative growth of legumes (Pal et al., 2021). An estimated 30% of the world's cultivated land is deficient in zinc. Extended zinc deficiency hampers vegetative growth, sexual development, granule zinc content, internode shortening, epinasty, and leaf size reduction. Zinc supplementation enhances the translocation of assimilates and seeds per pod while facilitating the conversion of carbohydrates to sugars and forming chlorophyll in plants. Mung bean is an excellent source of the amino acid lysine, frequently absent in cereals (Umar et al., 2023).

Third, among micronutrients, boron is primarily responsible for maintaining the integrity of plant cell walls and membranes. Boron is an essential element in numerous plant processes, like as cell wall stability and formation, structural and functional membrane integrity maintenance, and the transportation of sucrose or energy into the plant's growing parts (Bhatla et al., 2023). It is vital for maintaining the equilibrium between starch and sugar and facilitating the migration of carbohydrates and sugar. Boron is essential for protein synthesis and has also contributed to an increase in protein content. Boron deficiency impeded growth, resulting in a decreased ratio of roots to shoots and restricted concentrations of phosphorous, K, and Fe in both the shoots and roots of the plant. Additionally, boron impacts legumes' biomass production, leaf area, and plant height (Kohli et al., 2023).

A significant disparity exists between the global pulse productivity of 904 kg/ha and that of India (650 kg/ha) (Devi et al., 2021). This suggests substantial potential for the nation to enhance its pulse productivity. This discrepancy could be attributed to substandard seed quality, inadequate soil management, suboptimal crop production methods, rainfed cultivation, and other biotic and abiotic influences. The yield disparity can be reduced by ensuring a sufficient supply of high-quality seeds, implementing enhanced seed production techniques, and pre-sowing seed treatments such as priming and coating. Achieving favourable soil and atmospheric conditions for crop stand can be accomplished by enhancing seed germination performance via pre-sowing treatment. This research investigates the complex interaction in between the foliar application of Zn and B and its effects on primed mung beans. It aims to elucidate this novel methodology's physiological mechanisms and agronomic consequences.

This extensive investigation will employ a multidisciplinary strategy, incorporating agronomy, soil science, and plant physiology elements. This research endeavours to clarify the intricate connections among zinc, boron, and primed mung beans by conducting a comprehensive analysis of yield components, biochemical processes, and growth parameters. Through this endeavour, it hopes to provide significant perspectives that can educate on sustainable agricultural methodologies, encourage the best utilization of nutrients, and contribute to the ongoing dialogue surrounding worldwide food security amidst the challenges posed by climate change. As we commence this investigative endeavour, the possible ramifications of foliar application of Zn and B on primed mung bean cultivation emerge, offering the prospect of a more profound comprehension of the complex mechanisms that regulate plant nutrition and productivity.

HYPOTHESIS

Response to primed and foliar treatment of *Vigna radiata*.

RESEARCH OBJECTIVES

1. To determine the effect of seed priming with gibberellin, salicylic acid, and foliar application of zinc and boron on growth, yield and yield attributes of *Summer* and *Kharif* mung bean

2. To study the biochemical analysis under different treatments

3. To assess the seed priming treatments and foliar application of zinc and boron on quality parameters in *Summer* and *Kharif* mung bean

CHAPTER II

REVIEW OF LITERATURE

This chapter brought together the available information on different aspects of the present investigation, such as "Impact of Zinc and Boron Foliar Application on Growth and Yield in Primed Mung Bean (*Vigna radiata* L.).

Seed Priming

According to **Ibrahim *et al.* (2022)**, Plants commonly experience abiotic conditions, stressors, including salinity, heat, cold, dehydration, and heavy metals. These stresses elicit intricate plant responses, culminating in diminished growth and crop productivity. Seed priming confers upon plants an increased capacity to combat various stresses expeditiously and efficiently. As a result, phytohormone priming of seeds has become a significant method for alleviating the detrimental impacts of abiotic stress. This review examines the potential efficacy pytohormone priming in mitigating the damaging effects of abiotic stresses, the possible mechanisms by which this was achieved and the contribution of priming to crop production enhancement.

Hazra *et al.*, 2021 stated that poor crop establishment is the primary constraint on pulse production. Vigour at an early stage may be associated with increased yields. The primary factors contributing to the suboptimal productivity of pulses include inadequate establishment of plant stands and reduced pulse yields in adverse environmental conditions. Conversely, the appearance of profoundly rooted seedlings signifies their rapid germination before the upper soil strata become desiccated and crusted and enhanced crop establishment. Priming seeds is an up-and-coming technique with great potential for improving crop stand, increasing legumes' biological nitrogen fixation capacity (BNF), and maximizing the benefits of low-fertility soils by initiating germination processes without radicle emergence, significantly increasing legume yields.

In their study, **Kumar 2020)** said that seed priming entails immersing the seeds in water or a solution with a low osmotic potential prior to planting. Seed priming is a frequently employed technique that enhances the process of seed germination and the growth of seedlings, safeguarding plants from infections and unfavourable climatic circumstances. Seed priming techniques enhance seedling growth by promoting controlled water uptake, stimulating enzyme activation, starch disruption, ATP synthesis, and antioxidant defence enhancing seedlings stress tolerance.

Effect of Seed Priming with Gibberellin on Growth, quality, and Yield of Mung bean

Kaur *et al*., 2023 assessed seed germination, Cd-tolerance index, nitrogen and protein content and GA_3 role in reducing Cd toxicity. GA_3 resulted in enhanced functions of carbohydrate-metabolizing enzymes, amylase, and the antioxidant defence system while reduceing concentration of H_2O_2. GA_3 synthesis was instrumental in lowering Cd toxicity in mung bean; therefore, it could serve as a criterion for developing genotypes resistant to Cd stress.

Pradhan *et al*., 2022 experimented ten cowpea genotypes procured from Western Odisha farmers using randomized design with fourteen treatments replicated four times. Following a six-hour soaking period, the cowpea seeds were dried to their initial moisture content. The farmer-saved seed from Kantamal, Boudh, exhibited the highest performance in germination and seedling growth occurred first, followed by seeds from Rupra Road and Rairakhol, Sambalpur. Treatments with GA_3 at 50.0 ppm along with ammonium molybdate at 10.0 to 3.0 M further improved seed germination and seedling growth.

Nandan *et al*., 2021 investigated seed treatments with phytohormones on mung bean (Narendra Mung -1) yield during *Kharif* season using a (RBD) Randomised Blok Design with 3 replications and seven treatments. The seed priming treatment containing 100 GA_3 resulted in the highest germination percentage (90.25%). Significant improvements were observed in growth characteristics such as plant height, total dried biomass, chlorophyll Nitrogen content in green leaves, along with protein content in ripe seeds.when seed priming was conducted using GA_3-100ppm.

Hassan *et al*., 2021 studied that the performance of eight local mung bean (*Vigna radiata*) varieties was evaluated in the presence of two concentrations of Cd Cl_2 both in the presence of Cd alone and following priming with GA_3 and salicylic acid (SA) and proline solution. Pretreatment with proline and phytohormones before Cd treatment improved all morphological parameters by modifying antioxidant enzyme activity and resulting in a decrease in the concentrations of MDA and proline, as demonstrated by the results. Additionally, it was noted that GA_3 exhibited superior performance under a 0.3 mM Cd treatment. In contrast, SA proved an effective mitigating agent under a 0.50 mM Cd stress condition in all mung bean cultivars examined.

Chakraborty *et al*., 2021 conducted experiments at, BCKV, West Bengal on green gram in India. The germination vigour and percentage were observed to evaluate the impact of Ag-nanoparticle and GA_3 stimulation on the seed quality. When treatments and genotypes were compared, G6 (IPM-512-1) exhibited the maximum germination percentage in 2019 and 2020, at 93.41 and 93.86, respectively. G1 (Pusa Vishal) showed the maximum vigour index (1,899.182) and 1,897.412 among the genotypes subjected to interventions in 2019 and 2020, respectively.

Mishra *et al*., 2021 experimented Narendra Mung-1 with seven treatments in a randomised block design during the during the 2019 *Kharif* season ANDU, Ayodhya U.P. Three replications of a randomised Blok Design were used in employed to select the Narendra Mung-1 variety for seven treatments during the *Kharif* season 2019. The application of GA_3 at a concentration of 75 parts per million (ppm) via foliar spray was observed to be the most productive method in enhancing the following plant characteristics.

Devi *et al*., 2021 examined the impact effects of seed treatment before sowing, sowing times, while seasons on green gramme seed production and its quality. The treatments included soaking in water for eight hours, coating with 10.0 ml linseed oil, 50.0 gm of rhizobium, as well as 4 g Trichoderma per kilogram of seed; priming with 100.0 ppm $MnSO_4$, 1.00% neem leaf extract, 5.0 ppm of GA_3, and 1% KCl; and combining neem leaf extract priming with rhizobium coating. The seeds primed with GA_3, KCl, and $MnSO_4$ exhibited the highest efficacy in improving seed quality and yield. The *Kharif* season was inferior to the *Summer* season in yield and seed quality.

Reddy *et al*., 2021 carried out a field study on lentils during 2020–21 of rabi season at CAU, Imphal, using an RBD with eight treatments replicated three times (GA_3 (250, 500 ppm), IAA (250, 500 ppm), and IBA (100, 200, and 500 ppm). Out of all the treatments evaluated, priming with GA3 at a concentration of 500ppm (T3) demonstrated statistically significant improvements over the others in the following parameters: plant height of plant, root nodule count, plant initial fresh and dry weight, branch count, pod count, seed count, stover yield, and harvest index followed by IAA (500 ppm) and IBA (200 ppm).

Arun *et al*., 2020 a field trial on cowpea (Arka Garima) yield and water-use efficiency during *Summer* at IIHR, Bangalore, under limited water conditions. The seeds was primed using the following methods: hydropriming with water, GA_3, $CaCl_2$, ammonium molybdate, KBr, $MgNO_3$, and $ZnSO_4$ for 24 hours at a temperature of 15ºC. Across all irrigation regimes, seed priming enhanced LAI, RGR, CGR, and NAR. The results suggest that seed priming cowpea for 24 hours at a low concentration with GA_3 (100 ppm) or ammonium molybdate may be advantageous under optimal and limited water conditions.

Influence of seed priming with salicylic acid on mung bean growth, quality, and yield

Laishram *et al*., 2023 conducted the field study from 2018 to 2019 at the (PDDYIAS) Agricultural Research Farm in Utlou, Bishnupur District, Manipur, India. The results of the study indicates that seed priming with salicylic acid (SA) at a concentration of 200 parts per million (ppm) and increasing the foliar application of potassium nitrate (KNO_3) to 1.5%. Resulted in significant improvements in lentil yield (grain: 1104.80 kg/ha, stover: 1799.01 kg/ha, biomass: 2903.90 kg/ha), economics (total returns: ₹73617, net returns: ₹38729, benefit-cost ratio: 2.11), nutrient uptake (N, P, K), and protein content.

Ogunsiji *et al*., 2023 investigated the impact of salicylic acid (0.5 mM) on mung bean seedlings pretreated for four hours before sowing. The researchers utilized a salt and SA mixture added cumulatively in the following conditions Pretreated for four hours, seedlings showed enhanced photosynthetic metrics (chlorophyll a and b increased by 52% in Var. 155 vs. control), proline, protein, and antioxidant enzyme activity (POD, CAT), with Var. 155 outperforming Var. 145 in osmoprotectant responses and salt tolerance. The findings as mentioned earlier show that Var. 155 treated with SA exhibits substantial Osmoprotectant responses and salt stress tolerance. In contrast, Var. Demonstrates. 155 exceeds Var. 145.

Rao *et al*., 2023 investigated what effect salicylic acid and zinc have on green gramme (Vigna radiata L.) development in sandy loam using randomised block design with nine repeated treatments. The results showed that treatment T9-Zn (125ppm) + SA (200ppm) was effective. The outcome demonstrated notably elevated growth parameters, specifically. The height (35.14 cm), dried weight (6.64 g/plant), and growth rate (2.99 g/m^2/day) of the crop. Nevertheless, the treatment consisting of T9-Zn (125 ppm) + Salicylic acid (200 ppm) had a greater impact on yield attributes and parameters, including compared to the other treatments, pods plant^{-1} (21.22), seeds formed in per pod (11.35) and 1,000- grains weight (34.04 g) along with seed yield (1100.97 kg/ha), and straw yield (4471.00 kg/ha).

Bhargav *et al*., 2023 experimented phytohormones on black gram at the Crop Research Farm, SHUATS, Prayagraj, India during the 2022 Zaid season. The experimental conditions encompass varying concentrations of the Salicylic acid (SA) at 50 ppm, 75 ppm, and 100 ppm, as well as Gibberellic acid (15 ppm, 30 ppm, 45 ppm). Based on the outcomes, the treatment consisted of 45ppm GA_3 and 50ppm SA (Treatment 10). 15 and 40 DAS yielded the following values: maximal eight of plant (40.08 cm), plant dry weight (7.13 g/plant), pod count (36.27), seed count per pod (7.12), test weight (35.29 g), and seed yield of 29.3 (957.86 kg/ha).

Verma *et al*., 2022, stated that protective measures should be examined against whitefly injury to mung bean in northen India. Among these, the application of salicylic acid at 150.0 mg/l as a seed priming agent, followed by a foliar spray at the same concentration, resulted in a notably greater yield, a maximal percentage of disease control of 57.27%, and a decreased terminal PDI of 32.75%. The fruit yield of 523.30 kg/ha with a (%) disease control of 50.73% was generated by the treatment that included ashwagandha leaf extract at 10% as seed priming as well as a spray at 100 ml/L. This result was statistically equal to the neem findings.

Kaur et al. (2022) investigated SA (0.5 mM) priming under 80 mM salt stress on chickpea genotypes (GPF-2, PBG-7). SA improved biomass, photosynthesis, nodulation, and ROS scavenging, reducing oxidative stress and enhancing yield, with GPF-2 outperforming PBG-7.

Kaur *et al*., 2022 examined the effects of seed priming with SA (0.5 mM) under conditions of salt stress (80 mM) on the the 2 chickpea genotypes (Cicer arietinum L.) i.e. GPF-2 and PBG-7 were studied for their growth, nitrogen (N_2) fixation, photosynthesis as well as antioxidant defence system, and formation of reactive oxygen species (ROS). Priming or presoaking SA resulted in the preservation of biomass and photosynthetic efficiency, the prevention of nodule senescence, and a reduction in oxidative stress through improved activation of ROS scavenging machinery and enhancing yield, with GPF-2 outperforming PBG-7.

Makwana *et al*., 2022 conducted trials to investigate the impact of various salicylic acid (SA) concentrations on moth bean's phenolic composition and bioactivity. The germination process was carried out by subjecting the moth beans to priming with SA at different concentrations (0 ppm/l, 50 ppm/l, 100 ppm/l, 150 ppm/l, and 200 ppm/l). The outcomes indicated a statistically significant increase ($p \leq 0.05$) in total phenolics, flavonoids, and proline levels in the germinated samples compared to the raw moth beans. The findings indicated that seeds primed with SA have an enhanced antioxidant capacity and an inhibitory effect on enzymes, which could contribute to improving dietary health benefits.

Heidarian *et al*., 2021 investigated the impact effects salicylic acid (SA) on black bean seed germination grown in saline conditions. To achieve this, the researchers primed the seeds with varying concentrations of salicylic acid (0, 2, 10, and 20 mM) and subjected them to salt stress (0, 50, and 100 mM NaCl). SA priming protected Black legumes from the harmful effects of salt stress (10 mM). SA increased the percentage of germination of seeds by 72% and 45%, respectively, at 50 and 100.0 mM NaCl. By priming seedlings with 10 mM salicylic acid, their dry weight, seedling length and antioxidant activity of enzymes, while decreasing lipid peroxidation and hydrogen peroxide levels.

Sadeghipour *et al*., 2021 conducted experiments to determine whether salicylic acid can mitigate the toxicity of similar to mung beans. According to the findings, toxicity significantly decreased the amount of chlorophyll, the shoot and root biomass, the leaf area, the relative water content (RWC), and the seed yield. Additionally, it enhanced the antioxidant activity in enzymes such as glutathione reductase (GR), ascorbate peroxidase (APX), and MDA, proline, and the decrease in MDA level was offset by elevated proline as well as antioxidant enzyme activity. The chlorophyll value, shoot overall root biomass, leaf area in mungbean and seed production of SA-treated plants increased in As toxicity conditions. The results show that mung bean plants' ability to withstand the toxicity of As may be improved by exogenously administering SA.

Ceritoğlu *et al*., 2020 investigated the impact of various preparatory interventions on the germination characteristics of chickpeas grown in saline conditions. Experiments utilized five priming treatments and three salinity levels (50 mM NaCl, control, and 100 mM): salicylic acid, hydro-priming, 0.10 mM, as well as 0.3 mM, non-primed. Seed priming, an inexpensive and readily implementable method, enhances germination efficiency by controlling water consumption and enzymatic responses. While all treatments resulted in notable enhancements, the germination properties in this experiment were significantly enhanced by the 0.2 mM SA treatment.

Additionally, it was determined that the chickpea germination threshold is 0.2 mM salicylic acid priming, while higher concentrations exhibit inhibitory effects.

Dawar *et al*., 2020 investigated the impact of a growth hormone (SA) and a signal molecule (H_2O_2) on the development comprising mung bean (*Vigna radiata L.*) and the another crop cowpea (*Vigna unguiculata L.*). Following the preparation of three separate SA as well as H_2O_2 concentrations (0.5, 1%, or 2%), seeds were primed for five minutes with the solutions above. When mung and cowpea seeds were exposed to a concentration of 0.5%, enhancers observed in the field included shoot as well as root length and weight, nodule count, and pods' number, size, and weight additionally. In contrast, seeds primed with H_2O_2 exhibited an elevated performance index, ultimately leading to enhanced chlorophyll performance.

Salhy *et al*., 2020 experimented with the influence of Priming strategies as well as time of durations on mung bean (Vigna radiata L.) on mung bean at Qadisiyah, Iraq. The first element includes 3 types of priming: (a) hydro-priming (using distilled water) along with hormone-priming (using 75 mg L^{-1} of salicylic acid), along with nutrient-priming (using P at 0.6%) with KH_2PO_4 solution serving as a phosphorus source. The majority of hormone-primed seeds had the greatest germination rate of 86.7%, which was not substantially different from the nutrient-primed seeds (85.8%). However, the highest significant values for the following parameters were obtained after an 8-hour nutrient priming treatment: germination. These values were not significantly different from those obtained from the hydro priming treatment lasting 6 hours and hormone priming lasting 4 hours, except for shoot length.

Zinc foliar treatment affects Mung bean growth, quality, along production

Murshed, 2024 aimed to examine the effects of applying zinc along with boron foliar treatments on specific yield components of soybeans. A field experiment was undertaken in the agricultural season of 2021-2022 in the northeastern region of Homs, Syria. The experimental plots were assigned by a RBD (i.e. randomized block design), which comprised 3 replications and 4 treatments by foliar zinc (2 g/l) and boron (2 g/l) application during soybean flowering The results indicated that using boron and zinc in combination via foliar sprinkling improved seed yield, protein content, pods $plant^{-1}$, and pod weight $plant^{-1}$. The seed yield was greater than 50% under the combined treatment of zinc and boron compared to the control.

Rashid *et al.*, 2023 experimented to look at how soybean performance is affected by foliar applications of zinc (Zn) and nitrogen (N). Two factoring levels made up A. (i) applying a 2% urea solution topically on the leaves during the pod development stage (N1) and (ii) applying no N (control) (N0). Factor B consisted of four stages in total. Management of zinc (Zn) and the interaction between zinc (N) and zinc (Zn) management had a substantial impact on the yield contributing parameters and soybean yields. The combination of foliar N (2% urea) and a single foliar spray of 0.5% $ZnSO_4.7H_2O$ during the pod formation stage yielded comparable results across all yield-contributing characteristics. At the pod formation stage, the results demonstrate that a 2.00% urea solution combined with a particular foliar application of 0.50% $ZnSO_4.7H_2O$ increases soybean seed yield.

Hussain *et al.*, 2022 studied the impact of fortifying chickpea variety GNG-1958 with zinc (Zn) with boron (B) on yield and produced quality. A range of concentrations of foliar boron and zinc application was conducted, including the following treatments: In T6 (2.56 mg/g), the chlorophyll concentration was the highest, and in the control (1.18 mg/g) the lowest. Grain zinc and boron concentrations were 40.55 mg/Kg and 39.42 mg/Kg, respectively, with the highest amounts in T6 (43.63 mg/Kg). The findings indicate that combining zinc (0.5%) and benzoic acid (0.5%) applied foliarly resulted in the highest quality and quantity of chickpea crop production.

Mecarty *et al.*, 2022 experimented during Zaid season2020 at the agronomy research farm, SHUATS, Prayagraj (U.P.). In addition to micronutrients such as zinc, molybdenum, and cobalt, the researchers applied available N, P, and K fertilizers. Randomised Block Design was utilized to organize the experiment, and nine treatments were replicated three times. The experimental group treated with 20 kg/ha of RDF + $ZnSO_4$ + 10 kg/ha of B exhibited notably greater values than the other experimental groups for plant height Compared to the other treatments, the treatment involving RDF + Co at 1 g/kg (seed) produced a significantly higher dry weight (9.14 g/plant).

Hussain *et al.*, 2021 examine a study to evaluate how different zinc supplies and application techniques affect the allometry, yield, and particle biofortification of mung beans. Zinc sulpate (ZnSO4), zinc-EDDHA, and a mixture of 50% $ZnSO_4$ and 50% Zn EDDHA were utilised. This experiment incorporated three application methods: basal, foliar, and a combination of 50% basal and 50% foliar. The findings suggested that administering zinc enhanced mung bean's allometric characteristics and yield. In the controled treatment, the source of Zn ($ZnSO_4$) applied basally increased the amount of chlorophyll present, and the number of sympodial and monopodial branches. 10.0 kg ha^{-1} Zn basal application method appeared feasible to enhance mung bean productivity and increase Zn biofortification in grains.

Borah *et al*., 2021 conducted a field experiment having 0.5% Zn foliar application on garden peas at Assam Agricultural University (2018–2019). The objective was to investigate the impact of foliar zinc application on the garden peas (Pisum sativum L.) growth and yield: five different treatments along with four replications were used in the study. About attributes that are responsible for determining production, T3 (0.50% Zn) exhibited the maximum pod weight (6.63g), seed count (7.59), seed weight (3.6g), shelling percentage (55.6%), and pod yield (56.3g/plant; 14.7t/ha). T2 (0.25% Zn) produced the most significant number of legumes per plant (15.80), followed very closely by T3 (0.50% Zn). The findings indicate that the treatment containing 0.50% zinc application (T3) was the most effective in enhancing growth and yield-related attributes.

Diaz *et al*., 2021 executed an investigation employing a completely randomized experimental design comprising 10 replicates. Besides that 2 treatments were foliar sprays of either an aqueous suspension of ZnO NPs (150.0 mg−1) or an aqueous solution of $ZnSO_4$. In addition, the leaf application of zinc oxide in the form of nanoparticles (ZnO NPs) is compared to the foliar treatment of $ZnSO_4$ on the green bean cultivar. The concentrations of Zn^{2+} in the leaflets, stems, roots and legumes of chlorophyll a and b were considerably increased by applying ZnO NPs (15.40 μgg^{-1} and 11.04 μgg^{-1}). Zn^{2+} applications increased concentration and formation of sucrose as well; however, no discernible variations were observed in total flavonoids (TFl), total phenols (TP), or antioxidant capacity (AC). When Zn^{2+} was added to the pods and seeds, the concentrations of sucrose. The results showed that ZnO nanoparticle (150.0 mg/l) foliar spray on green beans increased Zn^{2+} in tissues, chlorophyll a/b, sucrose, and total phenols, enhancing biofortification.

Soni *et al*., 2020 experimented at the (MGCGV) in Chitrakoot Satna (M.P.), *Kharif* season 2018. The experiment looked at the effectiveness of foliar spraying mungbean with zinc and (Fe) iron. Utilizing a randomized block design with three replications, the experiment was organized. An absolute control, a 0.5% $ZnSO_4$ spray at FI. Significant improvements were observed in yield attributes and specific legumes per plant when a 0.5% $FeSO_4$ application was applied. The result shows that 0.5% ZnSO4 and FeSO4 foliar sprays increased mung bean seed yield by 14.69–47.16% over the control.

Gahlot *et al*., 2020 performed a experiment in field during the *Kharif* season (July to September 2018) at the Agriculture University, Jodhpur (India). The purpose of the experiment was to evaluate mungbean performance using soil treatment and zinc and iron foliar spray. The experimental design was randomised block design (RBD) and 3 replications. The treatment involved applying zinc sulphate and ferrous sulphate each to the soil at a rate of 25.0 kg ha^{-1} plus applying ferrous sulphate foliarly at a rate of 0.50% at 35 DAS. The zinc sulphate application or iron sulphate to the soil increased mungbean plant height, accumulation of dry matter in leaves, yield by 37.3% and straw yield by 34.6%. Hence, the findings indicate that mungbean growth parameters and yield can be significantly enhanced in western Rajasthan by administering zinc and iron sulphate to the soil at 25 kg ha^{-1} each.

Masih *et al*., 2020 investigated the impact in the 2019 growing season on the growth and production of greengram (*Vigna radiata L.*) at P and Zn concentrations. The researchers utilized the Samrat variety for the trial and employed a Randomised Block Design with 9 treatments replicated thrice. For treatment T6 [P at 60.0 kg ha^{-1} + Zn at 35 DAS or 45 DAS], shows the highest height of plant (45.31 cm), number of branches per plant (13.7), number of nodules $plant^{-1}$ (16.02), dry weight (10.04 g $plant^{-1}$), CGR (0.295 g m^{-2} day^{-1}), grains per pod (13.64). The treatment T6 produced the maximum net return (71992.72 ha^{-1}) among all other treatments.

Verma *et al*., 2020 conducted a pot experiment at the plant physiology department in Agriculture University, Kanpur, titled "Effect of foliar application of Zinc and Boron on growth and yield of Mungbean" (Wilczek) (Vigna radiata L.) during the 2018 *Kharif* season. This experiment had 7 treatments, were assigned in the CRD design with five replications. The application of B at a concentration of 300.0 ppm resulted in a statistically significant increase in height of plant, pods produced $plant^{-1}$, seeds per plant, 1,000-seed weight (g), and finally, grain production (g) per plant.

Haider *et al*., 2020 examined to determine the best mungbean genotype, and the zinc administration method was most effective in increasing cereal Zn biofortification and productivity. The NM-92 and the variety of mungbean having NM-2006 were cultivated by using 3 distinct zinc administration techniques and their combinations. The administration of zinc through soil and foliar resulted in a 63% increase in grain yield, while the combination of osmopriming, foliar, and soil methods led to a 79% increase in cereal zinc concentration in genotype NM-92. The results shows that Zn osmopriming + foliar + soil application on mung bean (NM-92) increased grain yield (90.3%) and Zn concentration (45.1–79%) across sites in Pakistan.

Raj *et al*., 2019 investigated the impact of seed invigoration interventions on nutrient absorption and availability. When seedlings are primed with 0.05% $ZnSO_4$ for four hours, the most excellent assimilation of NPK by the crop is observed; the solution also contains more available N and Zn in the soil and organic carbon. The highest values for zinc uptake by the crop and available soil K status were observed in seeds primed with ZnSO4 (0.05 per cent) for four hours in addition to Trichoderma viride (10 g kg^{-1}) seed treatment. The findings show that four hours of seed priming with 0.05% $ZnSO_4$ increases the uptake and availability of zinc while pelleting seeds with 100 mg kg-1 borax enhances the uptake and availability of boron in cereal cowpea.

Aboyeji *et al*., 2019 conducted a field with the objective was to investigate zinc and boron fertilizers' exclusive and combined impact on groundnut (Arachis hypogaea L) growth, seed yield, and quality. The experiment comprised four replicates of the RCBD design i.e. (randomized complete block design). Applying 8 kg of zinc per hectare had a considerable positive impact on the seed count, seed weight, seed production, and seed quality

Effect of foliar application of (B) on growth, quality, and production of Mung bean

Murshed *et al*., 2023 investigated to examine the impact of foliar zinc as well as boron treatment on certain soybean yield components in the northeastern area of Homs, Syria, throughout the 2021-2022 agricultural season. Four replications and interventions comprised the experimental plots, assigned to a randomized block design. The experimental setup comprised the following: a control (Zn0B0) that did not receive any zinc or boron application, zinc-only (Zn2B0) and boron-only (Zn0B2) solutions, and a combined (Zn2B2) solution of zinc and boron at 2 g/l. One application of the foliar spray occurred during the flowering phase. The results shows that the seed yield was greater than 50% under the combined treatment of zinc and boron.

Dhaliwal *et al*., 2023 investigated and examined the potential of nutrients specifically. The economic implications of Biofortification with boron (B), zinc (Zn), along with iron (Fe) on mungbean cultivation, as well as its effects on productivity, nutrient concentration, and absorption. Different proportions of RDF combined with 0.5% $ZnSO_4.7H_2O$, 0.5% $FeSO_4.7H_2O$, and 0.1% borax were utilized on ML 2056 mungbean variety in this experiment. The concurrent foliar application of Zn, B and iron (Fe) demonstrated remarkable efficacy in augmenting mungbean cereal and straw yields, with the highest recorded values being 6,133.0 and 944.0 kg ha^{-1}, respectively agriculture were substantially enhanced through the combined application of $ZnSO_4.7H_2O$ (0.50%) + $FeSO_4.7H_2O$ (0.50%) and borax (0.10%).

Pazhanisamy *et al*., 2023 studied the impact of boron and molybdenum application methods on chickpea growth indices in Bihar, India, throughout the Rabi 2019-2020 season. The split-split-plot design was utilized to replicate the results three times for six boron and molybdenum application methods, including the following: Boron basal (M1), Boron foliar (M2), Molybdenum seed treatment (M3), Molybdenum foliar (M4), Boron basal + Molybdenum seed treatment (M5), and Boron basal + Molybdenum foliar (M6). Result shows that the seed treatment combining Boron and Molybdenum (M5) had a comparable impact on growth and growth indices throughout all phenological phases as the foliar treatment combining Boron and Molybdenum (M6).

Zafar *et al*., 2023 carried out 3 field studies were conducted over two years to investigate the impact of foliar and soil treatment of the aforementioned nutrients on mungbean production and seed biofortification, respectively. Zinc (Zn), iron (Fe), and vitamin deficiencies impact more than fifty percent of the global population. Furthermore, in 2019 and 2020, foliar application of these nutrients at the onset of flowering increased Zn and Fe concentrations increased by 28% and 31%, respectively, whereas B contents increased by 98% and 116% above the control. According to the findings, putting Zn, Fe, as well as B to the soil improved mungbean yields. Furthermore, foliar treatment of these nutrients greatly increased the seeds Zn, Fe, and B contents.

Embadwar *et al*., 2023 experimented at the research farm of agronomy department, SHUATS (UP), during the Rabi season 2022. The treatments comprised three concentrations of each micronutrient: boron (B 1-0.25%), zinc (Zn 2-5 kg/ha), and boron (B 2-0.5%) and zinc (B 3-0.75%), respectively. Randomised Block Design (RBD) with three replication was use in this study. The application of Zinc in conjunction with Boron at a concentration of 0.75% resulted in notable improvements in the following plant attributes: plant dry weight (22.13 g), plant height (55.21 cm), there were 62.16 nodules per plant, 33.21 pods per plant, 1.30 seeds per pod, 3.09 t/ha of seed output, and 4.55 t/ha of stover yield.

Rashid *et al*., 2022 experimented with investigating the impact of foliar application with sugar alcohol (mannitol) at two concentrations (0, 10, and 15 g l^{-1}) and boron at three concentrations (50, 100, and 150 mg) in addition to the control treatment litre^{-1} on pea plant development and yield. The findings indicated that the application of mannitol at a concentration of 15 gm l^{-1} resulted in the most significant plant length, branch count, leaf area, pod count, seed count per pod, yield per plant, and total yield. Spraying with B at a concentration of 150 g l^{-1} resulted in the highest average values for plant length, maximum branches number, along with leaf area, leaves dry matter, quantity of pods, seeds pod^{-1} or plant^{-1} yield, and total yield.

Krishna *et al*., 2022 experimented at the Crop Research Farm, Department of Agronomy, SHUATS, (UP) in Zaid 2021. The experimental conditions consisted of 2 sources: zinc (applied to the soil at three various rates of 10.0 kg ha^{-1}, 12.50 kg ha^{-1}, and 15.0 kg ha^{-1}) and boron (applied in the form of foliar at three different rates of 0.1%, 0.2%, and 0.3%, respectively). The results show that the 15 kg/ha Zn + 0.3% boron foliar application havie highest plant height (44.08 cm), maximum number of branches per plant (6.04), maximum number of nodules per plant (6.33), dry weight of plants (6.20 g/plant), and CGR (2.62 g/m^2/day) in this experiment.

Poonguzhali *et al*., 2022 investigated the impact the effect of Boron (B) availability has an impact on groundnut in Madurai district's of (B)-deficient soil series. The researchers analysed the data using a randomised block design with 3 replications. The findings indicated that the highest nodule count and dry matter production occurred when 15.0 kg ha^{-1} of B was applied as a soil amendment, and 0.50 percent of B was used as a foliar amendment during critical growth phases of crop, in addition to the recommended dosage of fertilizers. Concerning quality, the interventions involving soil (15.1 kg/ha), foliar B (0.5%), and RDF exhibited the most significant quantities of oil and protein compared to the other approaches.

Fatima *et al*. 2021 A field experiment at the Faisalabad Agriculture University will determine the effectiveness of many micronutrients (Zn, Fe, Mn as well as B) on black gram. Three replications of a Randomized Complete Block Design (RCBD) were employed. Mash from Chakwal served as a test variety. The treatment combinations were aqueous spray at 25 DAS (days after sowing), spraying water at flowering stage, Mn (0.50%) at 25 DAS, Fe (0.50%) at flowering, Zn (0.50%) at 25 DAS, and B (0.50%) at flowering. The result showed that 0.5% Zn at 25 DAS + 0.5% boron at flowering increased black gram yield and grain micronutrients (Mn: 0.20, Fe: 7.60, Zn: 3.40, B: 0.09 mg/100 g). In summary, utilising Zn during the initial phases and B during the lateral stages is crucial for increasing mash bean yield.

Hoque *et al*., 2021 investigated to determine the impact influence of micronutrients on performance of chickpea growth and production. The trial included two variables: treatment variety and treatment quantity. There are two indigenous types, namely. Consider the BARI Chola-5 and 9 or the 5 regimens. Three replications of a randomized complete block design (RCBD) were utilized. Considerable variation was noted among the cultivars, with Chola-9 variety exhibiting the highest seed yield of 2.47 tonnes per hectare. T4 produced the maximum quantities of each: plant height, branch count, pod count, nodule count, effective pod count, pod length, weight of 1,000-grains, seed yield, yield of straw, and biological yield. The greatest seed production of 2.68 tonnes per hectare was reported in BARI Chola-9 when treated to a foliar treatment of (B) boron and seed priming with Mo of the chickpea variety BARI Chola-9.

Hasany *et al*., 2020 during the 2017-2018 farming season conducted a field experiment to study the effect of foliar feeding Nano-boron at three different doses (zero, 5, along with 10 mg^{-1}) on the growth and two faba bean crop productivity (i.e. Aquadlegi and Aquadols). The experiment used a split-plot design with three randomized sector replicates (R.C.B.D). The concentrations of nano-boron were placed in the secondary plots, while the varieties were placed in the main plots. The findings indicate that the application of Nano-boron sprays at a concentration of 10 mg l^{-1} resulted in enhanced pod length, pod number per plant, weight per 100 seeds, and total seed yield, with the highest average values of 25.00 cm and 16.57 pods, respectively—132.31 g per plant and 5576.0 kg ha^{-1}. The findings indicate that applying Nano-boron through irrigation on various cultivars significantly enhanced the pods produced per plant.

Elaziz *et al*., 2020 conducted two field experiments on broad bean plants during the 2014-2015 winter growing season at Alexandria state of Egypt. The purpose was to analyze the influence of different spacings (10.5, 20.5, evaluating 30.5 cm), three different rates of humic acid (1000 as well as 2000 mg) (control), and three different rates of boric acid (2.5 and 5.0 mg l^{-1}) on vegetative development, production of seeds, and results suggested that increasing the distance between broad bean plants resulted in a more significant branches numbers ($plant^{-1}$) and a lower percentage of defective seeds. Plants treated with boric acid having 2.5 mg l^{-1} exhibited the most excellent mean values of plant height (cm). Furthermore, as boric acid concentrations increased to 5.0 mg l^{-1}, reduces $plant^{-1}$ fresh mass. In contrast, the maximum average value of the percentage of ears and nodes established was attained by administering boric acid having quantity of 5.0 mg l^{-1}. The result showed that 5 mg/l boric acid foliar spray + 1000 mg/l humic acid at 10 cm spacing maximized broad bean seed yield.

Raj *et al*., 2020 investigated the impact of nutri priming cereal cowpea with borax and $ZnSO_4$ on early growth, seedling vigour, and zinc and vitamin B content. The seeds primed with $ZnSO_4$ at concentrations of 0.025 and 0.05% exhibited a germination index that was 1.4 times greater. Additionally, the mean daily germination and rapidity of germination were enhanced. When seeds are primed with 0.05% $ZnSO_4$, the germination rate index and coefficient rate of germination are at their peak. The findings indicate that Nutri priming with 0.025 or 0.05% $ZnSO_4$ effectively promotes early seedling growth, vigour, and increased zinc and B content in cereal cowpeas.

CHAPTER III

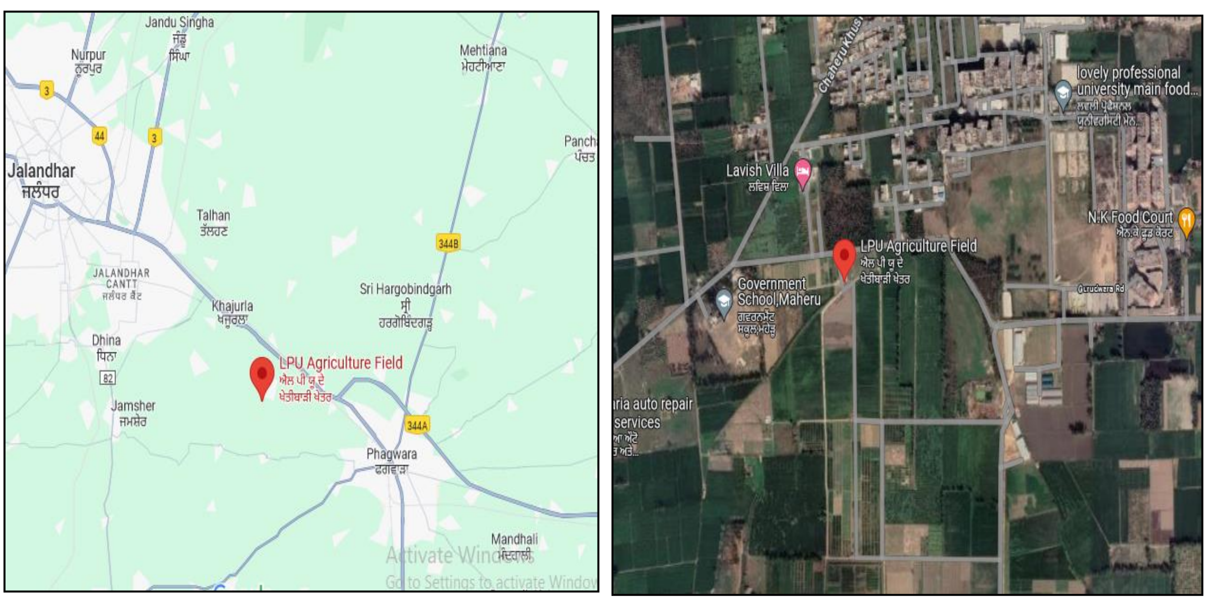
MATERIALS AND METHODS

The experiment entitled **"Impact of Zinc and Boron Foliar Application on Growth and Yield in Primed Mung Bean (*Vigna radiata* L.)"** was undertaken throughout the *Summer* along with *Kharif* season of 2022 and repeated in 2023 similar seasons at Research Farm of the School of Agriculture of Lovely Professional University is located in Phagwara, Punjab.This chapter discusses the specifics of the materials utilized and the methods employed in these studies. This chapter includes a detailed description of the experiment location, layout, land preparation, soil characteristics, meteorological data, and other agronomical practices used during the trial period.

3.1 Experimental Site

The study was conducted in 2022–2023 in the Research Farm of Lovely Professional University (LPU) School of Agriculture in Phagwara, Punjab. According to Google Maps, the farm is located at 31.244605 North longitude and 75.701021 East longitude, 240 m above sea level.

Fig. 3.1: Experimental farm, School of Agriculture



(Source: https://www.google.com/maps/d/viewer/mid)

3.2 Weather and Climatic Conditions

Phagwara is situated in the Trans-Gangetic Plains region of northern India, an area renowned for its distinctive agroclimatic conditions. The contested area is positioned in the lower foothills of the Himalayas, encompassing a fertile tract that is geographically positioned between the Sutlej and Beas rivers. Phagwara, situated at an average altitude of 241 m (765 feet), is a pivotal juncture for accessing the Himalayan area. There is a consensus that January experiences the lowest temperatures while June has the highest. Furthermore, June receives an average of 686 millimetres of precipitation. The monsoon season typically commences in early July or late June and continues through September 1. On average, 200 mm of rainfall are anticipated. The highest recorded temperature in June is 46 ºC, whereas the lowest temperature is recorded in January as 0 ºC. The initial relative humidity is determined to be 32%; throughout the investigation, it increases to 63%.

Table 3.2.1 Monthly Metrological weather data during trial period of 2022

Month	Maximum temperature (^{o}C)	Minimum temperature (^{o}C)	Relative humidity (%) max	Relative humidity (%) min	Rainfall (mm)
March	26.42	17.84	54.26	43.58	0.00
April	38.60	27.67	42.03	31.33	0.02
May	39.84	30.32	35.81	29.29	0.36
June	39.80	31.33	41.23	45.63	2.35
July	37.20	29.50	65.57	63.23	8.53
August	34.43	25.97	75.33	64.37	0.94
September	35.57	24.20	72.13	63.37	0.38

Table 3.2.2 Monthly Metrological weather data during trial period of 2023

Month	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%) max	Relative humidity (%) min	Rainfall (mm)
March	27.45	14.99	73.09	47.29	1.79
April	33.07	16.41	74.43	31.60	0.39
May	37.85	22.64	68.03	40.37	1.80
June	36.43	24.60	82.47	46.90	3.15
July	33.94	26.48	88.13	67.97	9.00
August	34.52	27.00	90.97	70.39	2.61
September	33.73	24.11	92.00	65.27	0.79

3.3 Collection of soil samples

Before field preparation, soil samples were collected from the designated field at a depth of 0–15 cm using a zigzag technique to assess the chemical and nutritional composition of the soil. After combining the soil samples in an even manner, 500 grams of soil were ultimately collected. Various soil attributes were evaluated using the sample. The fundamental physicochemical Table 3.3.1 shows the soil's qualities in detail.

Table 3.3.1: Chemical and available nutrient status of the experimental field in 2022 and 2023

S. no.	Particulars	2022	2023	Method
Chemical properties				
1.	Electrical Conductivity (ds m^{-1})	0.18	0.16	Electrical Conductivity (ds m^{-1}) (Sparks 1996)
2.	pH	7.35	7.29	pH meter Glass electrode (Sparks 1996)
3.	O.C. (%)	0.26	0.27	Titration method (Walkley and Black 1934)
Available Nutrient Status				
1.	Available Nitrogen (kg ha^{-1})	169.2	171.4	Alkaline potassium per magnate method
2.	Available Phosphorus (kg ha^{-1})	12.5	13.6	0.5 N NaHCO3 extractable Olsen method (1954)
3.	Available Potassium (kg ha^{-1})	201.3	210.8	Flame photometer method (Jackson 1973)
4.	Available Zinc (ppm)	0.89	0.91	AAS (Lindsay and Norvell 1978)
5.	Available Boron (ppm)	0.98	0.99	AAS (Lindsay and Norvell 1978)

3.4 Procedure details for chemical and nutrient status:

3.4.1 pH (Sparks, 1996):

a) Five grams of soil were added to one hundred millilitres of solution in a beaker. Following this, 25 millilitres of distilled water were introduced into the beaker,
b) The mixture was vigorously shaken for 30 minutes.
c) To determine whether the soil is alkaline, submerge the electrode in solution.

3.4.2 Electrical conductivity (ds m^{-1}) (Sparks 1996):

a) Five grams of soil were added to a container with a capacity of one hundred millilitres. Following this, 25 millilitres of distilled water were added to the receptacle.
b) After 30 minutes of stirring to create a homogeneous suspension, the sample was left undisturbed for 30 minutes. A sample of the mélange was then collected and analysed with a pre-calibrated electrical conductivity (EC) electrode.
c) The sample's reading was finally documented.

3.4.3 Organic carbon (%) (Walkley and Black 1934):

a) A 2g sample of dehydrated soil was systematically transferred into a 250 ml conical beaker. Then, 20 ml of a concentrated sulphuric acid solution and 10 ml of a 1 N potassium dichromate solution were added to the vial.
b) Shake the solution for one minute, and then allow it to rest for thirty minutes. A 200 ml distilled water was supplemented with 10 ml orthophosphoric acid.
c) To commence the titration procedure, it is advisable to incorporate five to six droplets introduce the diphenylamine indicator into the solution.
d) Following this, the titration can be performed using a 0.5 N ferrous ammonium sulphate solution, which transforms the violet colour into a brilliant green hue.

3.4.4. Available Nitrogen (kg/ha) (Subbaiah and Asija 1956)

a) Twenty grams of dehydrated soil were withdrawn and introduced into the micro-Kjeldahl distillation apparatus.
b) 25 ml of a 2.5% NaOH solution and 100 ml of a 0.32% $KMnO_4$ solution are added to the distillation vessel.

c) After adding 10 ml of boric acid to 150 ml of extract from the conical flask, three to four droplets of a mixed indicator were added.
d) Position the conical containers containing boric acid within the distillation apparatus at the lowest possible level relative to the receiving tube.
e) A volume of around 100 ml of distillate was gathered. The previously pink tint underwent a conversion into a shade of blue.
f) Following the distillation, 30 ml of the product was withdrawn into a conical flask and titrated with N/50 NaOH.
g) The final product was identified when the colour changed from pink to yellow.

3.4.5 Available phosphorus (Olsen method 1954)

a) The Olsen method (1958) was employed to calculate phosphorous.
b) 1 gram of soil is combined with 20 ml of sodium bicarbonate solution in a beaker.
c) Subsequently, incorporate a pinch of Darco-G and vigorously shake the mixture using an electric agitator for thirty minutes.
d) With the help of Whatman No. 1 filter paper the mixture was filtered. Likewise, the blank solution was prepared in the same manner.
e) Combine 5 ml of the filtered solution with 5 ml containing 1.5% ammonium molybdate in a container. Subsequently, ten millilitres of distilled water were added to the mélange.
f) Introducing one millilitre of stannous chloride into the solution led to the formation of a blue hue.
g) Following this, the absorbance was determined by utilizing a spectrophotometer that had undergone calibration to a specific wavelength of 560 nanometers.

3.4.6 Available potassium (Jackson 1973):

a) The potassium concentration was measured using 1N ammonium acetate method.
b) Incorporate 25 ml of ammonium acetate and 5 g of dehydrated soil into a 150-ml conical flask.
c) Shake the sample for five minutes using a mechanical agitator and filter it through Whatman No. 1 filter paper.
d) The extracted sample was then transferred to a beaker, and a 5 ml aliquot was taken for dilution.

e) After distinguishing the reading of K, an attenuated extract was atomized using a flame photometer.

3.4.7 Zinc and Boron analysis in soil Samples by AAS (Atomic Absorption Spectrophotometer) (Lindsay and Norvell 1978)

Lindsay and Norvell introduced the method in 1978. It employs diethylene triamine pentaacetic acid (DTPA) as the extractant. This technique has gained significant recognition for its ability to extract micronutrient cations, including zinc (Zn) simultaneously. The concentration of the extract's cations is determined using an atomic absorption spectrophotometer (AAS) and particular hollow cathode lamps.

Principle

The reaction of free metal ions in a solution with DTPA, a chelating agent, generates soluble complexes. An excessive dissolution of $CaCO_3$ introduces distortion to the results by potentially releasing occluded micronutrients inaccessible to plants, particularly in calcareous soils. This is avoided by adding soluble Ca^{++} to the extractant and subsequent buffering at a slightly alkaline pH range. Triethanolamine (TEA) is a buffer because it burns effectively during atomization. At pH 7.3, three-quarters of TEA is protonated ($HTEA^{+}$), which exchanges with $Ca2^{+}$ and a minor quantity of $Mg2^{+}$ produce the soil exchange sites. This results in a two- to three-fold increase in the concentration of calcium ions ($Ca2^{+}$), which inhibits the decomposition of $CaCO_3$ in calcareous soils. DTPA can complex each micronutrient cation to ten times its atomic weight.

Reagents

Solution for extraction:

a) Triethanolamine (TFA) comprises 0.005 M DTPA or 0.010 M $CaCl_2$, $2H_2O$, and 0.1 M.
b) pH should be adjusted to 7.3. Combine 1.967 g of DTPA and 13.30 ml of TEA in a 1l volumetric flask holding 200 mL of deionised water.
c) Combine 500 ml of deionized water with 1.47 g of $CaCl_2.2H_2O$ using the same volumetric flask.
d) Then, gradually incorporate the DTPA-TEA mixture into the flask until the overall volume reaches around 900 ml.

e) Decreases the pH to 7.3 with 1N HCl, pour one litre of the solution into the container, and agitate thoroughly.

a) Stock Solution

It was developing stock-standard solutions with salts of analytical grade for specific micronutrients. The chemical composition of the salt to be dissolved, its amount, along with the concentration of the appropriate stock solution. A 0.4398g sample of zinc sulphate ($ZnSO4.7H2O$) was dissolved in a one-litre solution containing 100 µg/ml stock concentration.

The standard working solution for Zn:

- For the preparation of a stock solution containing 10 ppm or 10 µg Zn/ml, Dilute 10 ml of the standard stock solution with DTPA extracting solution in a 100 ml volumetric vial until the desired concentration was reached.
- The stock solution (10 µg Zn/ml) was placed into a series of 100-ml volumetric flasks, each holding 8 ml. DTPA extraction solution was used to dilution each to the appropriate concentration.
- The outcome of this process was standard solutions containing zinc concentrations of 0.8 µg/ml or ppm, 0.1, 0.2, 0.4, 0.6, and 0.8 µg/ml.

Soil sample extraction:

a) For soil sample extraction, it is necessary to quantify 10 grams of air-dried, well-processed soil.

b) After that, the solution to a conical flask that has a 100-ml capacity was transferred. 20 ml of the DTPA extraction solution was added.

c) For precisely two hours, a stopper was placed on the flask and shaken on an electric agitator set to 25°C. Utilized Whatman No. 1 and 42 filter paper to filter the vessel's contents.

d) It was also ensured that the filtrate did not contain any colloidal materials.

e) A conical vial was used to store the filtrate for AAS analysis of zinc. After finishing each set, except for soiling, an empty set was also maintained.

Analysis of extracts

1. The zero on the instrument must be adjusted to zero.

2. Feed standards into the AAS to determine the absorbance or concentration of samples containing the specified element within the standardized range.

3. Following this, incorporate the DTPA extracts while recording the absorbance and concentration of the pertinent substances.

4. To proceed with each element, adhere to the procedures above.

3.4.8 Boron content determination

Gupta (1967) devised a method for rapidly and easily determining the B content of soil by removing the soil and placing it directly on a heated plate while boiling water. Deciding hot-water soluble B has been further simplified by substituting carmine or curcumin with azomethine-H (John et al., 1975). Under aqueous conditions, azomethine-H and H_3BO_3 combine to form a stable coloured complex with a concentration of proportional absorbance for several hours, irrespective of other salts, at a pH of 5.1.

Reagents:

1. **Buffer Solution:** A buffer the solution was made by dissolving 250 grammes of ammonium acetate and 15 grammes of EDTA (disodium salt) in 400 millilitres of distilled water, then stirring in 125 millilitres of glacial acetic acid.

2. Azomethine H Reagent: 0.45 g of Azomethine-H was dissolved in 100 mL of a 1% ascorbic acid solution. Preserved it in a chilled polypropylene container. Created a new, reusable solution once per week.

3. For the preparation of 100 milliliters of boron standard solution, dissolved 0.114 gramme of boric acid. H_3BO_3 of AR grade in distilled water was prepared. There was 20 g of B per milliliter in this solution. To obtain solution concentrations of 0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 2.0, 4.0, 6.0, 8.0, and 10 ppm, and 100 ml of this stock solution with deionized water was diluted, then 0.5, 1, 2, 3, 4, 5, 10, 20, 30, 40, and 50 ml, was added respectively and activated charcoal.

Procedure

a) Place 20 grammes of soil sample, which has been dried in the air and finely ground to a 20-mesh size, into a conical flask made of quartz or boron-free material with a volume of 250 ml.

b) Dispense 40 ml of deionized water. Boil 0.5 grammes of activated charcoal on a hot plate for a duration of five minutes.

c) Quickly strain using Whatman No. 42 filter paper.

d) Once the contents have reached the temperature of the surrounding room, move 1 ml of a blank solution, diluted B standard, or sample filtrate into polypropylene tubes with a capacity of 10 or 15 ml.

e) Dispense a volume of two millilitres of buffer.After adding 2 ml of Azomethine-H reagent, wait for 30 minutes, mix the solution, and then use a spectrophotometer to measure the absorbance at 420 nm.

f) Construct a standard curve by plotting the absorbance (Y-axis) against the concentration of B (ranging from 0 to 10 µg B ml-1) on the X-axis.

g) In order to ascertain the concentration of B in the aliquots, it is necessary to compare the absorbance readings of the sample aliquots with the standard curve.

3.5 Varietal description

Both cultivars were introduced by Punjab Agriculture University (PAU). Yellow mosaic disease does not affect SML 1827. Medium in size and gleaming green, the grains have excellent culinary qualities. Five quintals are produced on average per acre. ML1808 exhibits resistance to the Cercospora leaf spot, bacterial Leaf spot of mung bean yellow mosaic virus. The grains are bright green, moderately robust, and of high culinary quality. A quintal of cereal is produced on average per acre. Micronutrients and growth regulators were extracted from the laboratory of Lovely Professional University.

Fig: 3.5 Varietal Description

3.6 Agronomic Practices

To ensure optimum crop development, cultural practices were implemented using the prescribed package and practices of Punjab Agricultural University (PAU), Ludhiana.

3.6.1 Field Allotment

The experimental field was designated on Lovely Professional University's agricultural property during the *Summer Kharif* seasons of 2022 and 2023.

3.7 Treatment detail

The study titled "Effects of Foliar Zinc and Boron Application on Growth and Yield in Primed Mung Bean (*Vigna radiata* L.)" was performed on the field at the School of Agriculture, Lovely Professional University, Punjab. India, during the *Summer* and *Kharif* seasons, using the SML 1827 and ML 1808 genotypes of mung bean. A genotype of mung bean was obtained from the PAU in Punjab. A Randomized Block Design (RBD) was employed in the research to minimize experimental error, with treatments randomly assigned within each block to ensure unbiased comparisons. Each of the primary experimental plots measured 5 x 3 m^2. Using seed priming, gibberellin and salicylic acid were applied to mung bean seeds. Seeds are primed using salicylic acid at 150 mg/kg and gibberellin at 50 mg/kg. The foliar application of boron and zinc occurred 15 and 45 days after the sowing date, respectively. The prescribed practices for cultivating mung beans in Punjab were adhered to. A range of observations were documented at the harvesting stage and 30 and 60 days after sowing. Various experimental treatments, each denoted by a unique symbol, were applied to enhance crop growth. The control treatment, represented by T0, involved no additional applications. Seed priming with gibberellin at a concentration of 50 mg/L was designated as T1. Similarly, seed priming with salicylic acid at 150 mg/L was labeled T2. Foliar application of zinc sulphate (0.5%) at 15 and 45 days after sowing (DAS) was marked as T3, while foliar application of boric acid (1%) at the same intervals was denoted T4. A combined approach of seed priming with gibberellin (50 mg/L) and foliar application of zinc sulphate (0.5%) at 15 and 45 DAS was represented by T5. Likewise, seed priming with gibberellin (50 mg/L) paired with foliar application of boric acid (1%) at 15 and 45 DAS was assigned T6. Seed priming with salicylic acid (150 mg/L) combined with foliar application of zinc sulphate (0.5%) at 15 and 45 DAS was indicated by T7, and the same priming with foliar application of boric acid (1%) at those intervals was marked T8. A more complex treatment, involving seed priming with gibberellin (50 mg/L) and foliar application of both zinc sulphate (0.5%) and boric acid (1%) at 15 and 45 DAS, was denoted T9. Finally, seed priming with salicylic acid (150 mg/L) followed by foliar application of both zinc sulphate (0.5%) and boric acid (1%) at 15 and 45 DAS was represented by T10.

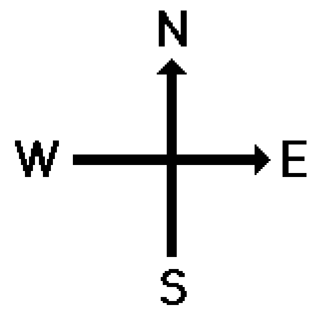
Table 3.7.1 Experimental design detail:

S. No.	**Particulars**	
1.	Location	Agriculture Research Farm LPU
2.	Crop	Mung Bean (*Vigna radiata L.)*
3.	Variety	SML 1827 (*Summer* Mung) ML 1808 (*Kharif* Mung)
4.	Design	Randomized Blocks Design (RBD)
5.	Treatment	Eleven
6.	Replication	Three
7.	No. of plots	11X3=33
8.	Gross plot area	$756m^2$
9.	Net plot of size	5X3 m^2
10.	Spacing	22.5x7cm (*Summer* Mung) 30x10cm (*Kharif* Mung)
11.	Year	2022 and 2023(both *Summer* and *Kharif* season)
12.	Method of application	Foliar Spray [with knapsack sprayer]

Table 3.7.2 Treatment details:

Name of treatment	The symbol used for each treatment
Control	T0
Seed priming with gibberellin (50mg/l)	T1
Seed priming Salicylic Acid (150mg/l)	T2
Foliar application of Zinc sulphate (0.5%) at 15 and 45 DAS	T3
Foliar application of Boric acid (1%) at 15 and 45 DAS	T4
Seed priming with Gibberellin (50mg/l) and foliar application of Zinc sulphate (0.5%) at 15 and 45 DAS	T5
Seed priming with Gibberellin (50mg/l) and foliar application of Boric acid (1%) at 15 and 45 DAS	T6
Seed priming with Salicylic acid (150mg/l) and foliar application of Zinc sulphate (0.5%) at 15 and 45 DAS	T7
Seed priming with Salicylic acid (150mg/l) and foliar application of Boric acid (1%) at 15 and 45 DAS	T8
Seed priming with Gibberellin (50mg/l) and foliar application of Zinc sulphate (0.5%) + Boric acid (1%) at 15 and 45 DAS	T9
Seed priming with Salicylic Acid (150mg/l) and foliar application of Zinc sulphate (0.5%) + Boric acid (1%) at 15 and 45 DAS	T10

Figure 3.7.2 Layout



R1	MAIN IRRIGATION CHANNEL	R2		R3
T_0R_1	SUB IRRIGTION CHANNEL	T_{10} R_2	SUB IRRIGTION CHANNEL	T_5R_3
T_1R_1		T_7R_2		T_3 R_3
T_2R_1		T_5R_2		T_8 R_3
T_3R_1		T_1R_2		$T_{10}R_3$
T_4R_1		T_8R_2		T_6R_3
T_5R_1		T_2R_2		T_0 R_3
T_6R_1		T_9R_2		T_1 R_3
T_7R_1		T_6R_2		T_4 R_3
T_8R_1		T_3 R_2		T_9 R_3
T_9R_1		T_2R_2		T_2 R_3
$T_{10}R_1$		T_4R_2		T_7 R_3

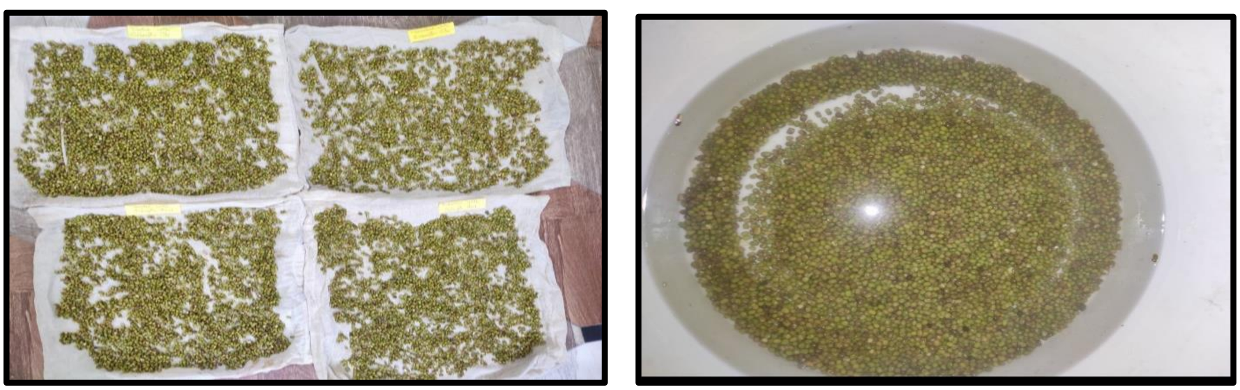
3.8 Field Preparation

After preparing the field with a tractor, the primary tillage operation was completed using a disc harrow. Secondary cultivation was performed in addition to the requisite levelling procedures.

Figure 3.8: Field Preparation

3.8.1 Seed treatment

Gibberellin (50 mg/l) and salicylic acid (150 mg/l) were used to observe a six-hour priming period before seed sowing.



1. Drying seeds after priming **2. Priming seeds in solution**

Figure: 3.8.1 Seed Treatment

3.8.2 Application of micronutrients:

Foliar micronutrient application was conducted 15 and 45 days after sowing using an appropriate sprayer.

Figure 3.8.2.: Micronutrient foliar application

3.8.3 Sowing

During the *Summer*, seeds were sown in flat beds with a row-to-row spacing of 22.5 cm along with a plant-to-plant spacing 7cm. During the *Kharif* season, seeds were sown on ridges with 30 cm x 10 cm dimensions. Light irrigation was applied to the plants.

1. **Sowing in Flat bed.**
2. **Sowing on Ridges**

Figure 3.8.3: Sowing of Seeds

3.8.4 Method of sowing and sowing time:

During the *Kharif* season, seeds were sown into beds placed 67.5 cm apart utilising bed planters (37.5 cm bed top and 30 cm furrow). Establishing spacing in bertween the row 30 cm and sowing in two rows per bed use the same amount of seed, fertilizer, and other cultivation materials techniques as with the flat-sown *Summer* moon. *Summer* mung bean was planted on March 20, 2022, and was sown again on March 23, 2023. The *Kharif* mung bean was initially sown on July 19, 2022, and again on July 23, 2023, for the second year.

3.8.5 Fertilizer application:

At the time of sowing, 5 kg of nitrogen (11.0 kg of urea) and 16.0 kg of phosphorus dioxide (100.0 kg of SSP) per acre were used.

3.8.6 Irrigation

Following the sowing procedure, irrigation was expeditiously implemented. The prevailing meteorological conditions applied varying intervals of irrigation. Maintaining a consistent irrigation schedule is essential for sustaining crop growth and development.

Figure 3.8.6 Irrigation

3.8.7 Tagging

Following germination, the density of the plants was preserved, and labeling was performed in each plot by selecting three plants at random from the net plot area. The data on the tagged plants' morphological and yield attributes were documented. The plants' dried, fresh, and fresh weights were extracted from the gross plot area after the destructive samples were removed for biochemical analysis.

3.8.9 Weeding

Two-handed weeding was performed during the trial period of a single season.

3.8.10 Harvesting

The mung bean harvesting process was completed during the *Summer* season, specifically after the second week of May. In the *Kharif* season, the harvesting was carried out during the ending week of Sep. or the first week of Oct., Sickles were used to cut the plants, which subsequently dried out or developed dark brown pods. Following crop cutting, disentangle the pods from the plant and, after two to three days of sun-drying, remove the seeds from the pods.

1. **Randomly through square shape quadrant** 2. **Harvesting crop**

Figure. 3.8.10 Harvesting Crop

3.9 Observation Recorded

3.9.1. Morpho- physiological parameters

3.9.1.1. Plant height (cm)

At 30-DAS, 60-DAS and at harvest plant height was recorded with the help of measuring scale from the tagged plants in plots.

Figure: 3.9.1.1 Plant Height (cm)

3.9.1.2. Number of branches (Plant^{-1})

The manual counting of branches per plant for tagged plants occurs at 30 and 60 DAS. Three tagged plants were counted for each branch in one plot, and the average value was noted.

3.9.1.3. Number of leaves (Plant^{-1})

At 30 and 60 days after planting, the leaf count per plant was determined by tallying the leaves from each branch of the tagged plants.

3.9.1.4 Number of nodules (Plant^{-1})

Following light irrigation, a plant was chosen randomly and carefully extracted from the soil using a kauri. Any excess soil was then removed with water. The number of nodules in the mung bean root was then tallied at 30, 60 DAS.

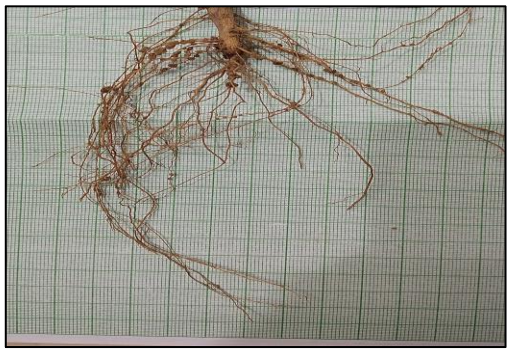


Figure: 3.9.1.4 Number of nodules

3.9.1.5 Leaf area (Plant^{-1})

Using a leaf area metre, leaf area was measured at 30-DAS, 60 DAS intervals; the mean leaf area was subsequently calculated in cm^2.

Figure: 3.9.1.5 Leaf Area (cm^2)

3.9.1.6 Days to 50% flowering

All replications underwent visual observation of 50% blossoming during the flowering days. The mean value of these three replications was then recorded.

Figure: 3.9.1.6 Days to 50% flowering

3.9.1.7 Root length (Plant^{-1})

Following light irrigation, a plant was chosen randomly and carefully extracted from the soil using a khurpi. Excess soil was then removed with water. The root length was determined using a measuring instrument at 30 and 60 DAS.

3.9.1.8. Fresh weight (Plant^{-1})

The weighing balance determined the fresh weight at 30, 60, and harvest time.

3.9.1.9 Dry weight (Plant^{-1})

At random intervals of 30, 60, and harvest, samples were collected and dried for three to four days in a hot air oven set at 70 degrees Celsius. The weight was subsequently noted in grams using a weighing balance.

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

The term "CGR," which stands for crop growth rate, denotes the measurable increase in the quantity of plant matter per unit area over a specific period. Watson's 1952 postulated approach can be used to compute this.

CGR= W2-W1/T2-T1 (In the given context, W2 denotes dry weight of the plant at the time T2, and W1 represents its dry weight at time T1.)

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

Williams first proposed the term in 1946. The "total increase in dry weight of a plant at two intervals" pertains to the aggregate increase in a plant's mass over a specified duration. The expression can represent the ratio of two units' dry weights during a specified period.

RGR= logeEW2- logeW1/T2-T1

3.9.1.12 Net assimilation rate (g cm^{-1} day^{-1})

Watson described the net assimilation rate (NAR) calculations in 1952. They are based on dry matter measurements acquired at different time intervals.

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

3.9.2 Biochemical parameters

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

a) Chlorophyll content is extracted with an acetone solution comprising 80% by volume.
b) The resulting absorbance was evaluated at 645nm and 663nm wavelengths.
c) The absorbance coefficient was used to determine the chlorophyll content quantity.

Reagent: pre-chilled 80% acetone

Procedure:

a) A 100-milligramme leaf sample was subjected to crushing using a solution comprising 20 ml of 80% concentration acetone.
b) Subsequently, with great care, the supernatant was transferred to a centrifuge tube in anticipation of centrifugation.
c) The supernatant obtained was transferred with care into a volumetric vessel after subjecting the mixture to centrifugation at 5000 revolutions per minute (rpm) for 10 minutes.
d) The supernatant volume was subsequently modified to 100 ml by adding 80% acetone.
e) Utilising a spectrophotometer, the absorbance was determined at 645 and 663 nanometers with a reference negative of 80% acetone.

The formula that is provided was used to quantify the chlorophyll content.

Chlorophyll = a (mg/g Fresh Weight) = 12.70*(A663)-2.69*(A645) x V1000 x W

Chlorophyll = b (mg/g Fresh Weight) = 22.90*(A645)-4.68*(A663) x V1000 x W

Total chlorophyll (mg/g Fresh Weight) =20.20(A645) +8.02(A663) x V1000 x W

Where W = the fresh weight of the leaves, V = the final volume of the extract, A = the absorbance at the specified wavelength. The value is expressed as milligrammes per gramme of fresh weight.

1. Chl estimation by spadmeter **2. Chl in leaves by Arnon (1949) method**

Figure 3.9.2.1: Chlorophyll Estimation

3.9.2.2 Total Soluble Sugar content (microgram/ml)

The anthrone reaction can efficiently and promptly calculate the total soluble sugar in a plant sample. The synthesis of furfural involves dehydrating carbohydrates in a solution of concentrated H_2SO_4. The 630 nm calorimetric measurement of the complex formed when furfural condenses with anthrone observes a blue-green hue.

Reagents: Ethanol (80%)

Anthrone reagent: 200 mg of anthrone was dissolved in 100 mL of ice-cold 95% sulfuric acid. Before using, I made a fresh preparation.

Standard glucose: Prepare stock of 100 mg glucose was dissolved in 100 ml water. To serve as a working standard, 10 ml of the stock was diluted with distilled water to a final volume of 100 ml.

Procedure:

a) A total of 10 millilitres of ethanol was used to fully breakdown 100 milligrammes of leaves.
b) The finely ground substance was subjected to centrifugation at a speed of 5000 revolutions per minute for a duration of 15 minutes.
c) After the process of centrifugation, the liquid portion that settled at the top, known as the supernatant, was moved to a container with a known capacity.

d) The volume was then modified to reach a total of 100 ml by adding distilled water.
e) Combine 1 millilitre of extract with 6 millilitres of anthrone reagent in a separate test tube.
f) After the test instrument had reached a lower temperature by being immersed in the water bath for a duration of ten minutes, it was cleansed by being exposed to a continuous flow of water.
g) A control sample was made using the same methods, with the exception that it did not include leaf extract.
h) The intensity of the blue colour was measured using a spectrophotometer at a wavelength of 620 nanometers. The sugar content was determined using the standard curve.

Preparation of the Standard Curve for Estimation of Total Soluble Sugar:

a) In order to establish a standard, 10 milligrammes of glucose were dissolved in 100 ml of distilled water, or alternatively, 10 ml of a standard glucose stock was diluted with 100 ml of distilled water.
b) Different concentrations of sugar solution were created by transferring specific amounts (0.2 ml, 0.4 ml, 0.6 ml, 0.8 ml, and 1.0 ml) of the stock solution into individual test containers.
c) The total volume of each test tube was then brought to 3 ml by adding distilled water, followed by the addition of 6 ml of the anthrone reagent.
d) The test tubes were then submerged in water and heated. After the solution cooled down, the intensity of the blue light at 620 nm was measured.
e) The absorbance value was plotted against the sugar concentration in the solution to generate the standard curve.

Figure: 3.9.2.2 Total Soluble Sugar Estimation

3.9.2.3 Total Soluble Protein content (microgram/ml)

Principle

The test is based on the finding that protein binding induces a change in the absorbance maximum of Coomassie Brilliant Blue G-250 from 465 nm to 595 nm when it is dissolved in an acidic solution. The stabilisation of the anionic form of the dye occurs due to both hydrophobic and ionic interactions, resulting in a change in the pigment. This experiment demonstrates the high practicality of the dye-albumin complex solution, as it maintains a constant extinction coefficient even when the concentration is increased by a factor of 10.

Reagents

7.4 pH sodium phosphate solution

Solution A: To produce the sodium phosphate buffer, 13.9 grams (g) of 0.1 M sodium dihydrogen phosphate (NaH2PO4) were dissolved in one litre (1000 ml) of distilled water.

To prepare the sodium phosphate buffer (Solution B), 26.82 grams of 0.1M disodium hydrogen phosphate (Na2HPO4) were dissolved in distilled water until the final volume reached 1000 millilitres.

The final pH was adjusted to 7.4 by combining solutions A and B in a 19:81 ratio, as determined by a pH meter.

Dye concentration: 100 milligrams of Coomassie Brilliant Blue G 250 should be dissolved in 50 ml of 95% ethanol. 100 ml of orthophosphoric acid should be added to the mélange. 200 ml should be added to the container using distilled water. When stored in the refrigerator, amber containers will preserve the solution for at least six months. I diluted the concentrated dye solution with distilled water in a 1:4 ratio. Filter any sediment that may be present by employing the Whatman No. 1 paper.

Procedure

a) After the initial processing, 100 mg of the plant material was transferred to a mortar and pestle.
b) Ten millilitres of cold extraction were added.
c) A fine slurry was produced by cursing the mortar while submerged in the ice container using the pestle.

d) 15 minutes were required for the centrifugation to attain 15,000 RPM.

e) A mixture was prepared by combining five millilitres of the diluted dye, two millilitres of the leaf crude protein extract, and eight millilitres of distilled water.

f) The mixture was allowed to rest for a minimum of five minutes and a maximum of thirty minutes. When protein-bound, the crimson dye transforms into a blue hue.

g) A spectrophotometer was employed to ascertain the absorbance at 595 nm.

Preparation of the Standard Curve for Estimation of Total Soluble Protein

a) The volume of bovine serum albumin (BSA) used to construct the standard curve varied between 0.1 and 1.0 ml.

b) The standard curve was generated by plotting the absorbance value against the solution's sugar content. The total soluble protein concentration is expressed in milligrams per milligram of sample.

Figure 3.9.2.3 Total Soluble Protein Estimation

3.9.2.4 The determination of membrane stability index (MSI) of mung bean leaf

MSI and solute (electrolyte leakage) from cells can be surrogate indicators of membrane injury. Plasma membrane damage could be the potential cause of stress's stimulatory effect on electrolyte leakage.

Reagent: Distilled water

Procedure

a) We combined 200 mg of leaves with 10 ml of double-distilled water in a test vessel.

b) They were cooked for 30 minutes at 40 degrees Celsius and 10 at 100 degrees Fahrenheit.

c) The electrical conductivity of the sample was subsequently determined using an EC meter after cooling it in flowing tap water.

d) The equivalent charge (EC) at 400°C is denoted as C1, while at 100°C it is denoted as C2.

The formula utilized to ascertain the MSI is as follows:

MSI= $\mathbf{100\ 1-C1/C2}$

Figure 3.9.2.4 MSI Estimation

3.10.3. Yield Attributes

3.10.3.1. Number of seeds /pod

Following a random selection of ten pods, the quantity of granules was quantified by counting.

3.10.3.2 Number of pods/plant

The pods count/plant from the three was manually recorded from the respective plots.

Figure 3.10.3.1 Weighing Pods

3.10.3.3. Pod length (cm)

Length of five pods were determined randomly from the tagged mung bean plants using a scale.

3.10.3.4 Test weight (gm)

Following the tallying of one thousand seed lots, the test weight was determined using a weighing balance.

3.10.3.5 Seed yield (q/ha)

A unit of one square metre was harvested from each experimental plot and threshed individually; the resulting yield was the data was then recorded and translated to quintals per hectare.

3.10.3.6 Biological yield (q/ha):

The plant's biological production was documented at the time of harvesting maturity. Following harvest and bundle formation, the harvested crop was weighed by allotment.

Figure 3.10.3.6: Biological Yield

3.10.3.7 Harvest index

To determine the biological yield, the harvested mung bean seed was weighed three to four days after it had dried in the field.

To convert economic yield to total biological yield HI was computed as a percentage by dividing the total value by 100.

3.11.4 Quality parameters

3.11.4.1 Seed protein (Kjeldahl method 1883)

A meal is broken down by a powerful acid, causing it to release nitrogen. This nitrogen may then be measured using an appropriate titration method. The protein content is then determined based on the nitrogen concentration of the meal. Proteins consist of chains of amino acids. The standard technique for estimating protein concentration is typically regarded as the most commonly used approach. The Kjeldahl technique requires the application of a conversion factor (F) to accurately determine the protein concentration from the observed nitrogen concentration, as it does not directly detect protein content. For various purposes, a conversion factor of 6.25 (which is equal to 0.16 g of nitrogen per gramme of protein) is commonly employed. The Kjeldahl technique may be easily separated into three steps: digestion, neutralisation, and titration.

Apparatus Used

For Digestion: Utilise kjeldahl flasks with a capacity ranging from 500 to 800 millilitres. Initiate the process of breaking down food by placing it on a heating apparatus set to raise the temperature of 250 ml of water from 25° C to a vigorous boiling point in roughly 5 minutes. To avoid superheating, add 3 to 4 boiling chips or glass beads.

For Distillation: Insert a rubber stopper into the flask, ensuring that the bottom end of a very effective scrubber trap or bulb is passed through it to avoid the mechanical transfer of alkali during the distillation process. Attach the upper part of the trap to a condenser using either rubber or glass tubing. Submerge the trap outlet of the condenser in a manner that guarantees the full absorption of ammonia that has been distilled into acid within a 500-ml Erlenmeyer flask.

Reagents:

1. **Concentrated Sulphuric Acid**: 25 ml .React with Ammonia.
2. **Sodium sulphate**: 8-10 g for adsorption of moisture.
3. **Cupric sulphat:** 0.5 g, it works as catalyst

1.1 Procedure :-

Protein Digestion:

a) Weigh sample about 1g, add cupric sulphate (0.5 g) and sodium sulphate (8- 10 g) on butter paper.

b) Put them in kjedahl flask. Add 25 ml concentrated H2SO4. Kept the flask on heating device for 2-3 hours to conduct protein digestion.
c) After that cool it for 10 – 15 minutes.
d) Protein Distillation-set the protein assembly, add distilled water in the kjheldhal flask and mix it.
e) Place the flask on one side upon the burner.
f) Place receiver on another side which contain H_2SO_4 + incdicator (methylene red).
g) After that neutralising the sample by adding NaOH (50% N) in the sample, do it until the sample become black in colour.
h) After that add 5 glass beads to avoid the bump and also add antic- foaming agent (1 drop to avoid foam).
i) Heat it till the collection of protein on the other Side of assembly and collect the sample in beaker approx 200 ml.

Titration: Fill the burette with 0.1 normality NaOH and neutralise the sample. On neutralisation sample become yellow in colour. Note the reading at which solution neutralise

Blank: fill burette with NaOH and in beaker add 50 ml H_2SO_4 (0.1N) and add indicator methylene blue and then titrate whenever yellowish color occur. Blank give accurate result.

Calculation:

$$\textbf{Protein} = \frac{(B-S) \times N \times 1.4007}{W}$$

Where,

B: Blank (titration value), S: Sample (titration value), N: Normality, W: Sample weight

3.11.4.2 Amino acids (tryptophan and arginine content by HPLC)

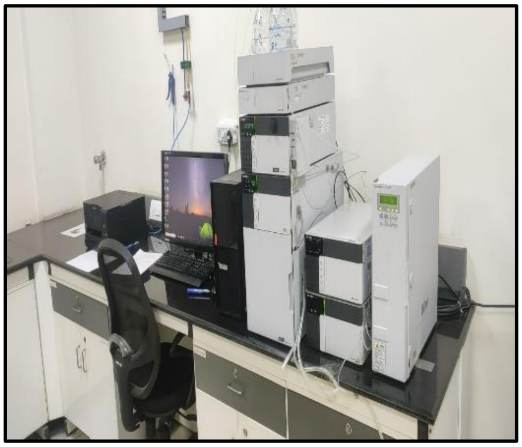
3.11.4.2a Method of Extraction (Seed)

To perform the quantitative determination of tryptophan, a volumetric flask was filled with 200 mg of the weighed seed powder. Following the addition of 20 ml of 70% ethanol to the volumetric vial, the sample was left to macerate overnight. Following extraction, the double-layered Whatman filter paper was used for filter the solution. After labelling the purified extract, it was collected for HPLC analysis.

$$\frac{\text{Sample Area x Std Dilution x Std. Purity}}{\text{Std. Area} \quad \text{Sample Dil.} \quad 100} \text{ x } 100 = \text{Assay\%}$$

3.11.4.2b HPLC analysis of extract

a) The extract (seed powder) was analysed by HPLC by using the method described by (Torre et al., 2013).
b) By using Shimadzu system consisting of an SPD-M20A Photodiode array detector (PDA).
c) The column that was used in this anlaysis was CTO-10ASvp with column oven temperature 30(degree celcius).
d) Mobile Phase (A) was made with 0.5 formic acid, Mobile phase (B) was made with acetonitrile (gradient) for tryptophan. The flow rate was maintained at 1ml/min.
e) The standard sample was made by 25ppm of argenine.
f) The wavelength of the detector was 210nm. By correlating the retension time of the peakes found in extract and the peaks found in standard, were able to identify the compounds.
g) The extract (seed powder) was analysed by HPLC by using the method described by (Alkaitis et al., 2016).
h) By using Shimadzu system consisting of an SPD-M20A Photodiode array detector (PDA). The column that was used in this anlaysis was CTO-10ASvp with column oven temperature 50(degree celcius).
i) Mobile Phase (70:30) (A) was made with MeC N (Acetonytrile: water), Mobile phase (B) was made with H_2O (water) for arginine.
j) The flow rate was maintained at 1ml/min. The standard sample was made by 25ppm of trypthophan.
k) The wavelength of the detector was 210nm.
l) By correlating the retension time of the peakes found in extract and the peaks found in standard, were able to identify the compounds.



1. HPLC Machine **2. Samples**

Figure: 3.11.4.2 Amino acid Estimations

3.11.5 Economic analysis

The significance of economics in shaping farmers' acceptance and adoption of any practice cannot be overstated. The economics of various treatments were estimated to maximise net profit per acre.

3.11.5.1 Cost of cultivation

The total input cost for each treatment was calculated using current market prices for fertilizers, manures, seed, irrigation, agrochemicals, labour, harvesting, and other crop production expenses.

3.11.5.2 Gross returns

The gross return of an investment represents its investment return before any deductions or expenses.

3.11.5.3 Net Returns

Following the subtraction of cultivation expenses, the net profits were determined.

3.11.5.4 Statistical analysis

The results were statistically analysed using ANOVA. The data was analyzed using OP Stat software using Duncan's multiple range test (DMRT) with a least significant difference (LSD) at a significance level of $p<0.05$.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment entitled **“Impact of Zinc and Boron Foliar Application on Growth and Yield in Primed Mung Bean (*Vigna radiata* L.)”** was conducted during the during the *Summer* and *Kharif* season of 2022 and repeated again in 2023 same seasons, at Research Farm of Agricultural School, Lovely Professional University, Phagwara, (India). This research investigated the impact of micronutrients foliar application on growth and yield of mung bean crop that primed with different growth hormone. The data was taken at 30, 60 days after sowing or at harvest in both *Summer* and *Kharif* season of 2022 or 2023.

This field experiment evaluated morphologically and yield attributes parameters that lead towards the quantity of mung bean and the biochemical and seed quality parameters that enhance the quality of produced mung bean. In the first part morpho-physiological parameters of the mung bean the 30, 60 DAS and at harvest was investigated under seed priming effect with Gibberellin, salicylic acid and foliar application of zinc and boron in all treatments. The second part represents the biochemical responses of mung bean plant under different treatments at 30, 60 DAS and at harvest. The last part deals with the yield of mung bean crop and quality parameters, which directly affect the quantity and quality of mung bean, produce.

In the previous chapter, all the details of the experiment are already given. In this chapter, an attempt has been made to describe and explain the recorded data on different growth stages. The data has been represented in tabular form as well as graphically. The results of two year research work findings are explained.

4.1 Morphological Parameters

4.1.1 Germination percentage (%)

The effect of seed priming with gibberellin, salicylic acid and foliar application micronutrients on germination percentage (%) was observed in *Summer* and *Kharif* season in mung bean crop during 2022 and 2023. The data of germination percentage (%) was recorded in between 1st week after sowing (Table 4.1.1.1, 4.1.1.2 and Figure 4.1.1.1a, 4.1.1.2a). In *Summer* 2022 it was recorded that the maximal percentage of germination was ocured in treatment T1 (95.2%) and T9 (95.2%) followed by T2 (92.9%), T5 (92.9%), T10 (92.9%) and T7 (90.5%). The minimum percentage of germination was found in treatment T0 i.e. control (76.19%) followed by T4 (76.2%) and T3 (78.8%). In *Summer* 2023 it was recorded that the highest percentage of germination was found in treatment T1 (95.2%) and T6 (95.2%) followed by T2 (92.9%), T5 (92.9%), T7 (92.9%), T9 (92.9%) and T10 (92.9%). The minimum percentage of germination was found in treatment T0 (73.80%) followed by T4 (78.6%) and T3 (81%).

Table 4.1.1.1 Effect of various treatments on germination percentage (%) in mung during *Summer* season 2022 and 2023

Treatments	Germination (%) *Summer* 2022	Germination (%) *Summer* 2023
T0	76.19^{c}±1.15	73.81^{c}±0.58
T1	95.24^{a}±0.58	95.24^{a}±0.58
T2	92.86^{a}±1.00	92.86^{a}±1.00
T3	78.57^{bc}±1.00	80.95^{bc}±0.58
T4	76.19^{c}±1.15	78.57^{c}±1.00
T5	92.86^{a}±1.00	92.86^{a}±1.00
T6	88.10^{abc}±0.58	95.24^{a}±0.58
T7	90.48^{ab}±0.58	92.86^{a}±1.00
T8	90.48^{ab}±1.53	90.48^{ab}±0.58
T9	95.24^{a}±0.58	92.86^{a}±1.00
T10	92.86^{a}±1.00	92.86^{a}±1.00
CD	11.90	10.40
SE(m)	4.04	3.52

In *Kharif* 2022 it was recorded that the maximal percentage of germination was occured in T9 (96.6%) and T10 (96.7%) followed by T5 (93.3%), T6 (93.1%), T7 (90%) and T1 (90%). The minimum percentage of germination was found in treatment T0 (73.3%) followed by T4 (76.7%)

and T3 (80%). In *Kharif* 2023 it was recorded that the maximal percentage of germination was found in T5 (93.3%) followed by T1 (90%), T6 (90%), T8 (90%), T9 (90%) and T2 (86.7%). The minimum percentage of germination was found in treatment T4 (76.6%) followed by T0 (80%) and T3 (83.3%). Seed priming is a pre-sowing treatment that involves the hydration of seeds to a point where germination processes are initiated but not completed. GA_3 is known to break seed dormancy and promote the germination. This could have faster and more uniform germination **(Arun *et al*., 2022).** Salicylic acid is known to induce stress tolerance. Priming mung bean seeds with SA can improve germination rate under abiotic stresses i.e excess temperature, drought and salinity. In plants SA plays a critical role in (SAR) systemic acquired resistance, which helps in defending against pathogens. The results are in agreement with **Hasan *et al*., 2022; Ogunsiji *et al.,* 2023).** Seed germination is controlled by several extrinsic as well as intrinsic factors and occurs when conditions are favorable. Amongst such factors, PGRs such as gibberellins (GA) play an important role in seed germination **(Afzal *et al*., 2019).**

Table 4.1.1.2 Effect of various treatments on germination percentage (%) of mung during *Kharif* season 2022 and 2023

Treatments	Germination (%) *Kharif* 2022	Germination (%) Days *Kharif* 2023
T0	73.33^{d}±0.58	80.00^{bc}±1.00
T1	90.00^{abc}±1.00	90.00^{ab}±1.00
T2	86.67^{abcd}±0.58	86.67^{abc}±0.58
T3	80.00^{bcd}±1.00	83.33^{abc}±0.58
T4	76.67^{cd}±0.58	76.67^{c}±0.58
T5	93.33^{ac}±0.58	93.33^{a}±0.58
T6	93.33^{ac}±0.58	90.00^{ab}±0
T7	90.00^{abc}±1.00	86.67^{abc}±0.58
T8	86.67^{abcd}±1.15	90.00^{ab}±0
T9	96.67^{a}±0.58	90.00^{ab}±0
T10	96.67^{a}±0.58	86.67^{abc}±0.58
CD	13.68	10.61
SE(m)	4.64	3.60

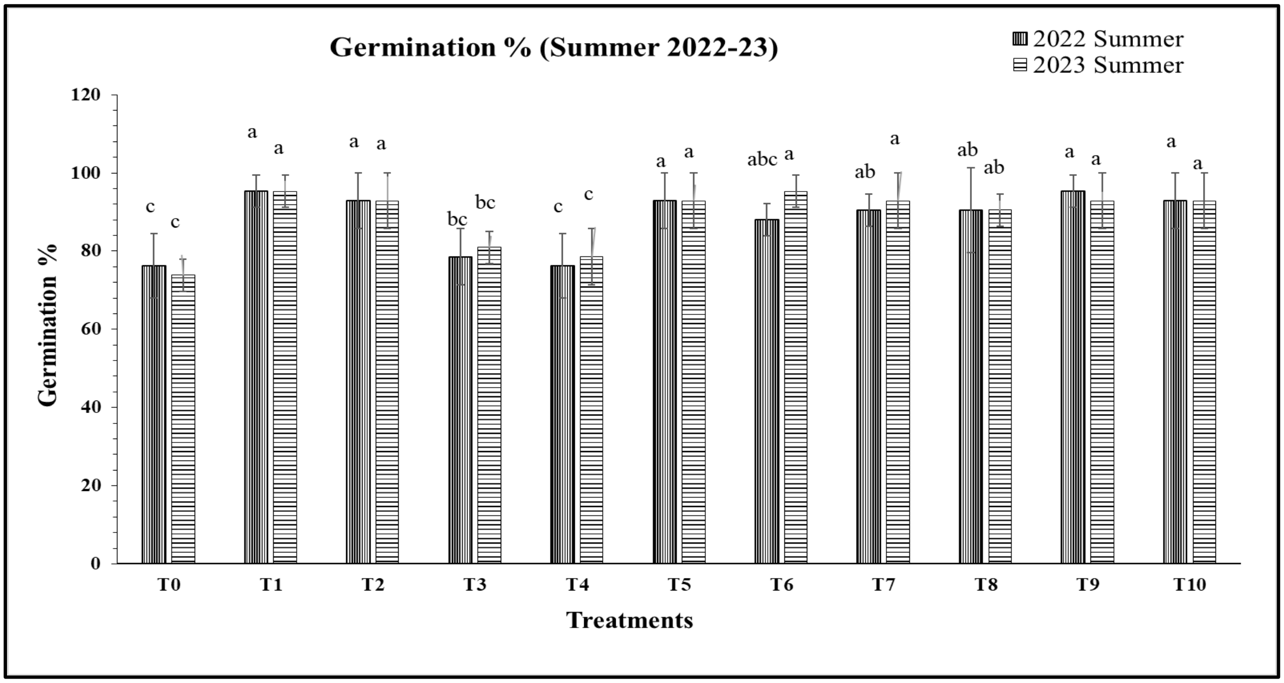


Figure 4.1.1.1a Effect of various treatments on germination percentage (%) in mung during *Summer* season 2022 and 2023

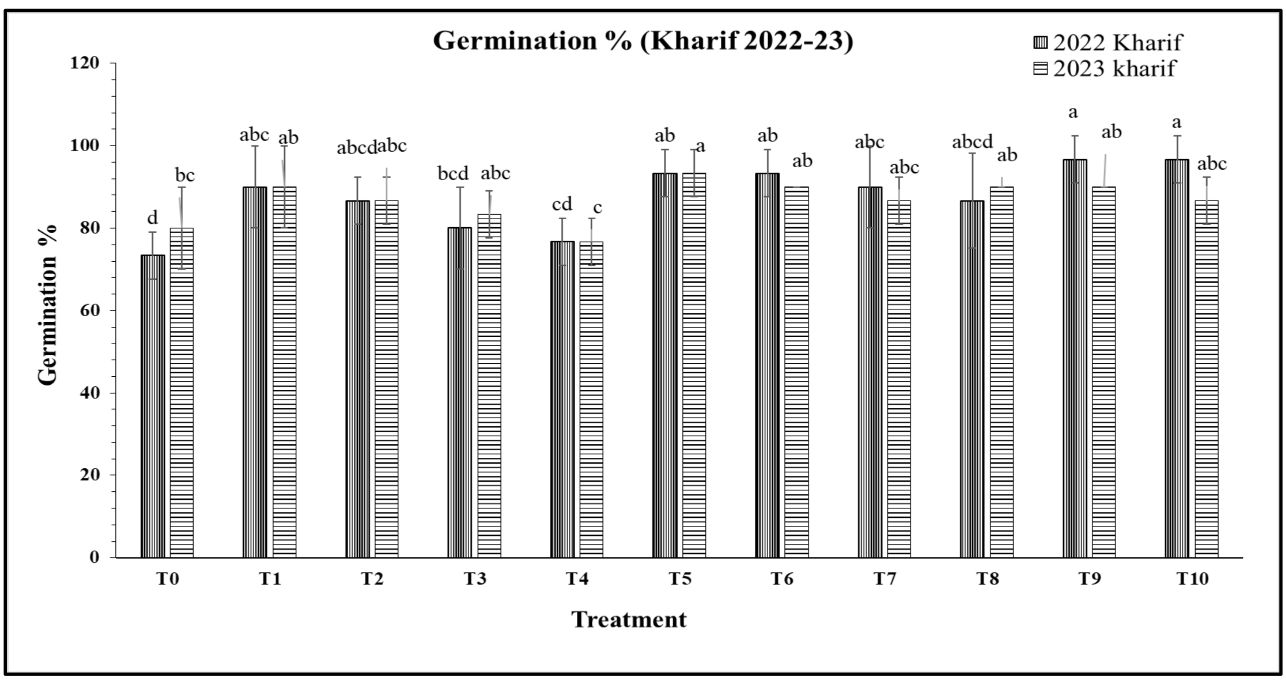


Figure 4.1.1.1a Effect of various treatments on germination percentage (%) of mung during *Kharif* season 2022 and 2023

4.1.2 Plant Height (cm)

The effect of priming seeds with gibberellin, salicylic acid and micronutrient foliar application on height of plant was observed in *Summer* and *Kharif* season in mung bean crop during 2022 and 2023. Plant height data was recorded at 30 days after sowing, 60 days after sowing interval and at harvest (Table 4.1.2.1, 4.1.2.2 and Figure 4.1.2.1a, 4.1.2.2a). In 2022 and 2023, plant height percentage has significant difference by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that the maximum plant height was found in T9 (69.71 cm) followed by (T10) (67 cm) at harvest and plant height of treatment T9 at harvest was significantly maximum as compared with all other treatments and it was found at par with treatment T10. The lowest height of plant was found in control (T0) (58 cm) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and it was found at par with single phytohormones priming i.e. T1 and T2. The percentage of plant height was increased in T9 by 33.3%, 13.2% at 30, 60 DAS interval or 16% at harvest when compared to the treatment T0 (control). It was also observed that percentage of plant height was lowest in control (T2) i.e. 20.7%, 5.4% and 5.2% at 30, 60 and at harvest respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. In *Summer* 2023 the maximum plant height was found in T9 (63.97 cm) followed by (T10) (62.03 cm) At harvest and plant height of treatment T9 At harvest was significantly maximum as compared with all other treatments and it was found at par with treatment T10. The minimum plant height was found in control (T0) (54.63 cm) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and it was found at par with single phytohormone priming i.e. T1 and T2. The percentage of plant height was significantly increased in treatment T9 (i.e. combined foliar application of Zinc and boron in gibberellin primed seed plants) 35.3%, 17.2% and 14.6% at 30, 60 DAS or at harvest respectively as compared to treatment T0 (control). Similarly, it was found that the treatment T7 enhanced the percentage of plant height by 4.9%, 1.9% and 4.4% at 30, 60 DAS and at harvest respectively when compared with treatment T3 (i.e. individual foliar application zinc). It was also observed that percentage of plant height was lowest in treatment (T1) (i.e. individual application of gibberellin primed seeds) i.e. 32.2%, 9.5% and 10.9% at 30, 60 and at harvest respectively when compared with treatment (T6). Overall, the results from *Summer* 2022 and 2023 show that treatments T9 and T10 consistently resulted in the highest plant heights. The control treatment T0 consistently had the lowest plant height, while treatment T9 showed the most significant percentage increase in plant height compared to the control.

Table 4.1.2.1 Effect of various treatments on plant height (cm) of mung bean at 30, 60 and at harvest during *Summer* season 2022 and 2023

	Plant height (cm) *Summer* 2022 and *Summer* 2023					
	30DAS		**60DAS**		**at Harvest**	
Treatments	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
T0	11.00^{f}±0.50	9.33^{e}±1.04	54.83^{d}±2.25	50.57^{c}±2.70	58.00^{d}±3.00	54.63^{d}±2.70
T1	11.17^{f}±0.76	10.83^{cde}±0.76	56.67^{cd}±2.25	52.8^{c}±2.06	59.17^{d}±1.75	56.53^{cd}±3.22
T2	11.50^{ef}±0.50	10.50^{de}±1.32	56.00^{cd}±2.00	51.97^{c}±2.73	59.00^{d}±3.00	56.03^{cd}±3.32
T3	12.50^{def}±0.50	11.60^{cd}±1.00	58.33^{bcd}±2.51	54.03^{bc}±2.50	61.17^{cd}±2.75	57.53^{bcd}±2.24
T4	12.17^{def}±0.76	11.23^{cd}±0.96	57.00^{bcd}±2.00	53.2^{bc}±2.52	60.5^{cd}±2.50	57.23^{bcd}±3.25
T5	14.83^{bc}±1.04	12.60^{bc}±1.15	60.00^{abc}±2.50	55.17^{bc}±1.36	63.83^{bc}±2.25	61.47^{abc}±2.33
T6	13.50^{cd}±1.32	12.33^{bcd}±0.96	59.17^{abc}±2.02	55.37^{bc}±3.30	62.00^{cd}±2.50	60.6^{abc}±2.06
T7	14.50^{bc}±1.32	12.20^{bcd}±0.50	59.17^{abc}±1.75	55.1^{bc}±2.95	62.23^{cd}±1.72	60.2^{abc}±2.70
T8	12.83^{de}±0.06	12.03^{bcd}±0.28	59.00^{bc}±2.50	54.57^{bc}±2.75	61.17^{cd}±1.75	59.1^{abcd}±3.26
T9	16.50^{a}±0.86	14.43^{a}±1.36	63.17^{a}±2.25	61.07^{a}±3.91	69.17^{a}±0.76	63.97^{a}±2.55
T10	15.83^{ab}±0.76	13.60^{ab}±1.21	61.00^{ab}±1.73	58.37^{ab}±2.70	67.00^{ab}±1.50	62.03^{ab}±3.00
CD (at p≤ 0.05)	1.3	1.7	3.51	4.82	3.42	3.15
SEm (±)	0.44	0.57	1.18	1.62	1.15	1.06

In *Kharif* 2022 the maximum plant height was found in T9 (68 cm) followed by (T10) (66.1 cm) At harvest and plant height of treatment T9 at harvest was significantly maximum as compared with all other treatments and at par with treatment T10. The minimum plant height was found in control (T0) (56.2 cm) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and it was found at par with single phytohormones priming i.e. T1 and T2. The percentage of plant height was significantly increased in treatment

T10 (i.e. combined foliar application of Zinc (Zn) and boron (B) in salicylic acid primed seed plants) 26.4%, 13% and 14.9% at 30, 60 DAS and at harvest when as compared to control (T0). It was also observed that percentage of plant height was lowest in treatment (T4) i.e. 3.8%, 2.4% and 3.3% at 30, 60 and at harvest respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023 it was recorded that the maximum plant height was found in T9 (66.43 cm) followed by (T10) (64.84 cm) At harvest and plant height of treatment T9 At harvest was significantly maximum as compared with all other treatments and it was found at par with treatment T10. The minimum plant height was found in control (T0) (55 cm) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and it was found at par with single phytohormones priming i.e. T1 and T2. The percentage of plant height was increased in T10 by 40.7%, 16.9% and 15% at 30, 60 DAS and at harvest as compared to the control T0. Similarly, it was found that the treatment T8 (i.e. foliar application of boron in salicylic acid primed seed plants) enhanced the percentage of plant height by 11.8%, 5.5% and 4.8% at 30, 60 DAS and At harvest respectively when compared with treatment T2 i.e. individual priming of seeds with salicylic acid. Overall, the *Kharif* season data from 2022 and 2023 demonstrates consistent results where treatments T9 and T10 achieved the highest plant heights. The control treatment T0 remained the lowest in plant height, while treatment T10 showed a significant increase in plant height compared to the control across both years. Both the *Summer* and *Kharif* season crop of mung bean plant height was slightly greater in *Summer* season as we compare to *Kharif* season, crop of *Summer* season plant height was better. As we compare both the 2022 and 2023 year crops, plant height of crop growing in 2022 year performs well as compare to crop grows in 2023 seasons. Mung bean seeds primed with GA_3 and followed by foliar applications of Zn and B have shown increased plant height compared to untreated seeds. GA_3 effectively stimulates cell elongation, particularly in stems, while Zn facilitates auxin synthesis, and B contributes to cell wall formation and nutrient transport. Combined, these treatments significantly boost the plant's growth potential, leading to taller plants. The similar results were obtained by **Nile *et al.,* 2020; Islam *et al.,* 2023**. The combination of GA_3 priming and foliar application of (Zn+B) can have a synergistic effect on plant growth, as each component supports different aspects of development. Boron plays a role in the transport of sugars and nutrients within the plant **(Pasala *et al.,* 2022)**. Whereas adequate zinc can improve overall plant vigor, including height, by facilitating enzyme function and protein synthesis. This can result in increased plant height as the hormone promotes the elongation of internodal regions. Similar results were obtained by **Day *et al.,* 2020; Rahman *et al.,* 2020; Islam *et al*., 2021; Kaur *et al*., 2023**.

Table 4.1.2.2 Effect of various treatments on plant height (cm) of mung bean at 30, 60 and at harvest during *Kharif* season 2022 and 2023

	Plant height (cm) *Kharif* 2022 and *Kharif* 2023					
	30DAS		60DAS		at Harvest	
Treatments	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
T0	10.73^{d}±1.04	7.00^{g}±0.50	52.17^{d}±2.61	49.60^{e}±2.94	56.27^{d}±2.61	55.00^{f}±1.80
T1	12.57^{bcd}±1.04	7.20^{efg}±0.76	54.40^{cd}±2.22	51.50^{e}±1.80	58.10^{cd}±3.30	57.67^{def}±1.75
T2	11.9^{cd}±1.32	7.50^{fg}±0.50	53.60^{cd}±2.81	50.33^{e}±2.02	57.60^{cd}±3.30	57.17^{ef}±2.02
T3	12.9^{bc}±1.00	8.50^{defg}±0.50	55.60^{abcd}±2.50	53.00^{de}±1.32	59.10^{cd}±2.45	59.70^{cde}±1.91
T4	12.73^{bc}±0.76	8.20^{defg}±0.76	54.83^{bcd}±2.61	52.27^{de}±2.25	58.77^{cd}±3.40	59.20^{cde}±1.47
T5	13.73^{abc}±1.25	10.50^{bc}±0.86	58.20^{abc}±2.96	56.77^{bc}±1.53	63.10^{abc}±2.45	62.40^{bc}±2.26
T6	13.57^{abc}±1.04	9.50^{cd}±0.50	57.13^{abcd}±3.05	55.70^{bcd}±1.80	62.23^{bc}±2.21	60.83^{cde}±2.25
T7	13.4^{bc}±0.50	8.80^{de}±0.76	56.60^{abcd}±3.00	56.00^{bcd}±2.29	61.77^{bcd}±2.75	61.33^{bcd}±2.51
T8	13.23^{bc}±0.28	8.70^{def} ±0.28	56.17^{abcd}±2.75	55.33^{cd}±1.52	60.77^{bcd}±3.40	60.03^{cde}±1.74
T9	15.4^{a}±1.32	12.50^{a}±1.53	61.03^{a}±3.65	61.17^{a}±2.25	68.00^{a}±2.50	66.43^{ab}±2.05
T10	14.57^{ab}±1.25	11.80^{ab}±1.60	59.97^{ab}±2.85	59.27^{ab}±1.85	66.10^{ab}±3.65	64.87^{a}±2.30
CD (at p≤ 0.05)	1.8	1.38	4.82	3.55	3.2	3.34
SEm (±)	0.6	0.28	1.62	1.19	1.07	1.12

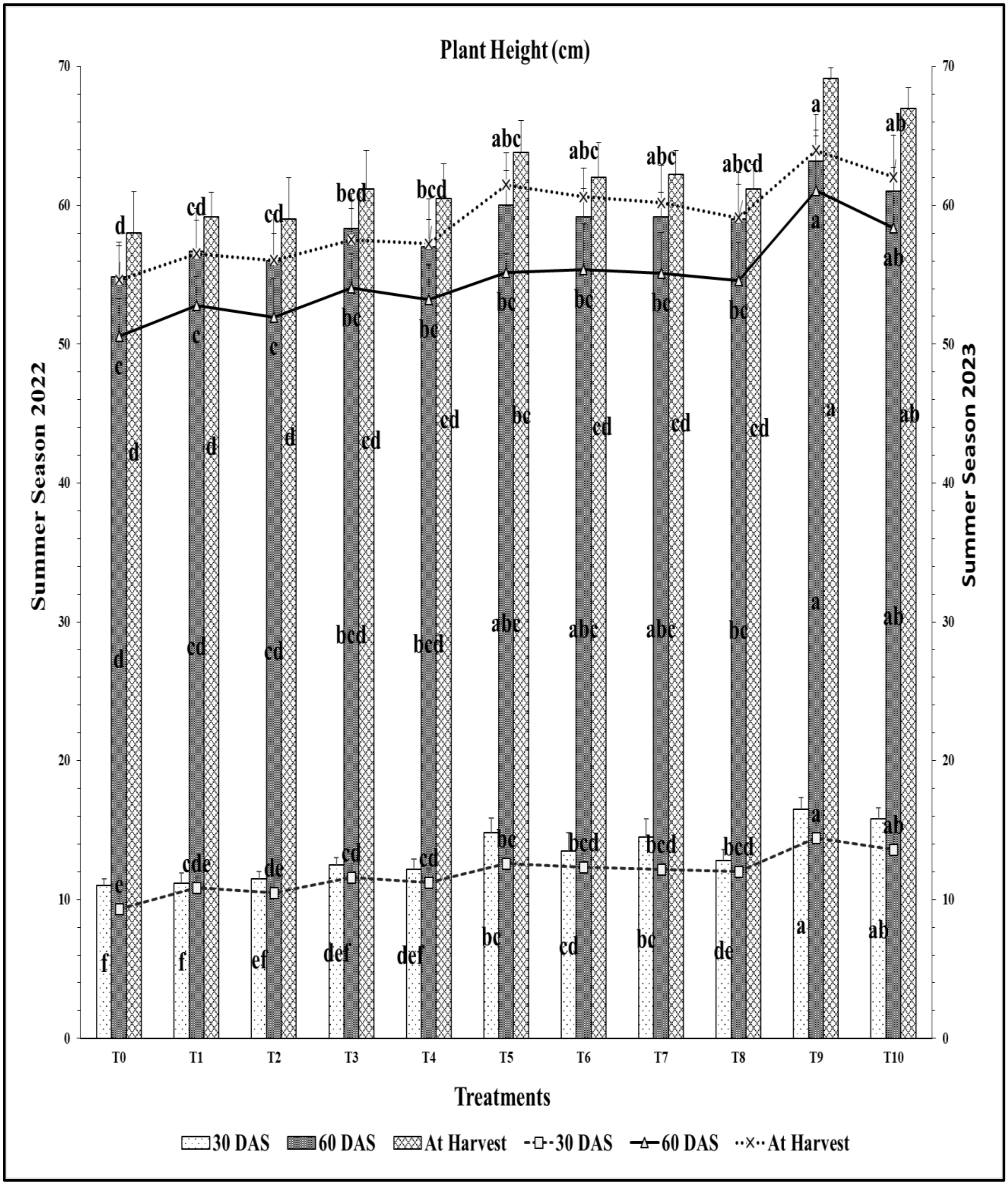


Figure 4.1.2.1a Effect of various treatments on plant height (cm) of mung bean at 30, 60 and at harvest during *Summer* season 2022-23

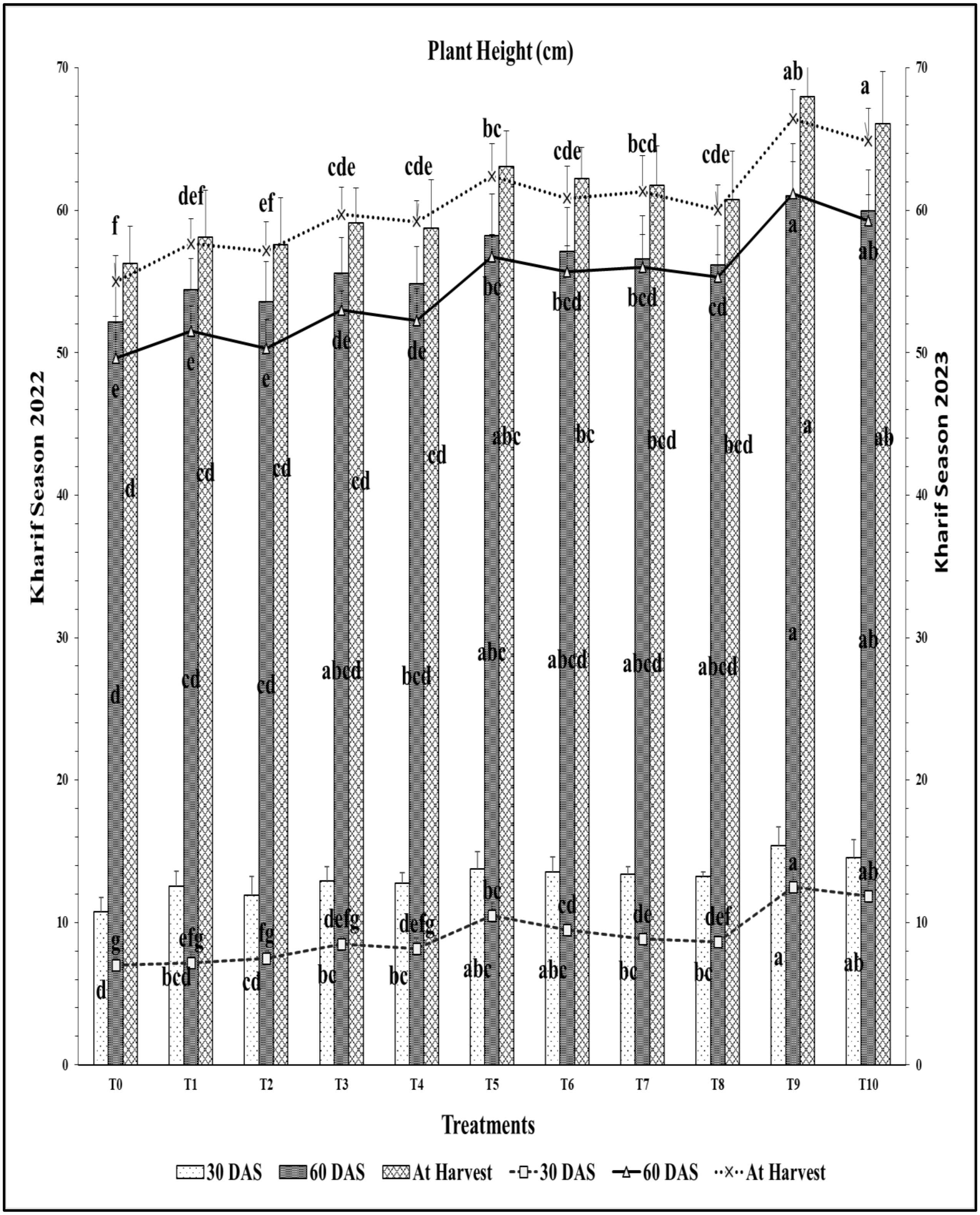


Figure 4.1.2.2a Effect of various treatments on plant height (cm) of mung bean at 30, 60 and at harvest during *Kharif* season 2022-2023

4.1.3 Number of Leaves (Plant^{-1})

The effect of seed priming with gibberellin, salicylic acid and micronutrient foliar application on leaves number was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data ofvleaves number was noted at 30 and 60 DAS (Table 4.1.3.1, 4.1.3.2 and Figure 4.1.3.1a, 4.1.3.2a). During both 2022 and 2023, significant difference were observed in the leaf count percentages due to phytohormone priming and the foliar application of micronutrients. In the *Summer* of 2022, it was noted that treatment T9 had the highest number of leaves at 41.37, followed by T10 at 39.07 at 60 DAS. The minimum number of leaves was found in control (T0) (31.43) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and found at par with single phytohormones priming i.e. T1 and T2. The percentage of number of leaves was increased in T9 by 28.5% at 30 DAS or 24% at 60 DAS as compared to the treatment T0. It was also observed that percentage of number of leaves was lowest in control (T2) i.e. 19% and 13.3% at 30 and 60 DAS respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. In *Summer* 2023, it was recorded that the maximum count of leaves was present in T9 (38.47 cm) followed by (T10) (36.23 cm) at 60 DAS. The minimum leaf count was observed in the control group (T0) at 27.70, significantly lower than those treated with phytohormone priming and the combined foliar application of zinc and boron. However, it was at par with the leaf count of plants treated with single phytohormones, such as T1 and T2. The percentage of number of leaves was significantly increased in treatment T9 (i.e. combined foliar application of Zinc and boron in gibberellin primed seed plants) 32.9% and 28% at 30 and 60 DAS respectively when we compared it with control i.e. treatment (T0). Similarly, it was found that the treatment T7 enhanced the percentage of number of leaves by 4.1% and 6.7% at 30 and 60 DAS respectively when compared with treatment T3 (i.e. individual foliar application zinc). Overall, the results from *Summer* 2022 and 2023 show consistent performance, with treatments T9 and T10 producing the highest number of leaves. The control treatment T0 consistently had the lowest leaf count, while treatment T9 showed the most significant percentage increase in the number of leaves compared to the control.

Table 4.1.3.1 Effect of various treatments on number of leaves/plant of mung bean at 30 and 60 DAS during *Summer* season 2022 and 2023

	Number of leaves/plant *Summer* 2022 and *Summer* 2023			
	30 DAS		**60 DAS**	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	$16.67^{e}\pm 2.52$	$13.03^{c}\pm0.57$	$31.43^{c}\pm4.61$	$27.7^{d}\pm2.33$
T1	$17.67^{cde}\pm2.08$	$13.83^{bc}\pm0.67$	$33.47^{bc}\pm4.05$	$30.37^{cd}\pm2.26$
T2	$17^{de}\pm2.00$	$13.67^{bc}\pm0.65$	$32.7^{bc}\pm4.67$	$30.1^{cd}\pm2.92$
T3	$19.67^{abcde}\pm2.52$	$14.8^{bc}\pm0.66$	$34.7^{abc}\pm4.30$	$31.33^{cd}\pm2.14$
T4	$18.67^{bcde}\pm2.52$	$14.3^{bc}\pm0.50$	$34.13^{abc}\pm3.43$	$31.2^{cd}\pm3.00$
T5	$21.67^{abc}\pm1.53$	$15.77^{b}\pm1.38$	$37.83^{abc}\pm4.10$	$34.37^{bc}\pm1.62$
T6	$20.67^{abcde}\pm2.08$	$15.4^{b}\pm0.98$	$37.1^{abc}\pm3.70$	$33.63^{bc}\pm2.18$
T7	$21^{abcd}\pm1.73$	$15.43^{b}\pm1.93$	$37.7^{abc}\pm4.07$	$33.57^{bc}\pm2.04$
T8	$20.33^{abcde}\pm2.52$	$14.4^{bc}\pm1.65$	$36.4^{abc}\pm3.85$	$32.73^{bc}\pm2.97$
T9	$23.33^{a}\pm1.53$	$19.43^{a}\pm1.30$	$41.37^{a}\pm1.56$	$38.47^{a}\pm0.95$
T10	$22.17^{ab}\pm1.76$	$17.73^{a}\pm1.08$	$39.07^{ab}\pm1.50$	$36.23^{ab}\pm1.86$
CD (at $p\leq 0.05$)	2.53	2.00	5.12	3.87
SEm (±)	0..85	0.67	1.72	1.3

During the *Kharif* season of 2022, there was a significant increase in the percentage of leaf count in treatment T10 (foliar application of combined zinc (Zn) and boron (B) in salicylic acid-primed seed plants), with increments of 21.1% and 25.5% observed in DAS of 30 and 60 respectively, compared to the control i.e. treatment T0. Similarly, it was found that the treatment T5 enhanced the percentage of number of leaves by 20.7% or 15.2% at 30 and 60 DAS respectively when compared with treatment T1 (i.e. individual application of gibberellin primed seed plants). It was also observed that percentage of number of leaves was lowest in treatment (T4) i.e. 2.1% and 6.2% at 30, and 60 DAS respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023 it was recorded that the percentage of number of leaves was increased in T10 by 28.3% at 30 and 25.8% at 60 DAS respectively as compared to the control T0. It was also observed that percentage of number of leaves was lowest in control (T3) i.e. 6.7% and 11.4% at 30 and 60 DAS respectively when compared with treatment (T5) i.e. foliar application of zinc in gibberellin primed seed plants. Overall, the *Kharif* season data from 2022 and 2023 indicates that treatments T10 and T5 were effective in increasing the number of leaves, with T10 consistently showing the highest percentage increase in leaf count compared to the control across both years. The control treatment T0 remained the lowest in terms of leaf count, while other treatments like T8 also demonstrated improvements in leaf count compared to their respective controls. Both the *Summer* and *Kharif* season crop of mung bean number of leaves was slightly greater in *Summer* season as we compare to *Kharif* season, number of leaves in the crop of *Summer* season was higher. As we compare both the 2022 and 2023 year crops, number of leaves of crop growing in 2022 year performs well as compare to crop grows in 2023 seasons. The promotion of cell division and elongation in the meristematic regions with the help of gibberellic acid, leading to the development of more leaves and enhances early growth ensures that the plants quickly establish a larger leaf area (**Umair *et al.,* 2020; Aslam *et al.,* 2023**). Foliar application of zinc enhances enzymatic functions that are essential for leaf development, chlorophyll production, and promoting leaf growth. Increased leaf number and improved chlorophyll content due to zinc boost the plant's photosynthetic capacity, thereby supporting overall growth (Nehar, 2020). A higher number of leaves generally leads to an increase in the fresh weight of the plant, as leaves contribute significantly to the plant's biomass. Plants with more leaves usually show vigorous growth and increased height because leaves are the primary sites for photosynthesis, driving overall growth. Similar results also corroborated with **Kaur *et al.,* 2023; Shoaib *et al.,* 2022; Wasaya *et al.,* 2020.**

Table 4.1.3.2 Effect of various treatments on number of leaves/plant of mung bean at 30 and 60 DAS during *Kharif* season 2022 and 2023

	Number of leaves/plant *Kharif* 2022 and *Kharif* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	14.67^{c}±0.58	12.67^{c}±12.67	28.37^{g}±1.63	27.63^{f}±2.04
T1	15.33^{bc}±0.58	13.00^{c}±13.00	30.8^{efg}±2.52	29.87^{ef}±2.40
T2	15.33^{bc}±0.58	13.00^{c}±13.00	30.27^{fg}±1.60	29.10^{ef}±1.78
T3	16.33^{bc}±0.58	14.00^{c}±14.00	32.63^{def}±2.85	31.10^{de}±1.40
T4	15.67^{bc}±0.58	13.67^{c}±13.67	31.93^{def}±1.39	30.93^{de}±1.89
T5	17.33^{b}±1.15	15.00^{c}±15.00	36.33^{bc}±1.56	35.10^{bc}±1.40
T6	17.00^{b}±1.00	14.33^{c}±14.33	35.1^{bcd}±1.42	34.10^{c}±1.41
T7	17.00^{b}±1.73	14.67^{c}±14.67	35.27^{bcd}±0.97	34.43^{bc}±0.86
T8	16.00^{bc}±1.73	14.67^{c}±14.67	34.03^{cde}±2.32	33.03^{cd}±1.65
T9	21.00^{a}±1.00	20.33^{a}±20.33	40.13^{a}±1.44	39.17^{a}±1.33
T10	19.33^{a}±1.15	17.67^{b}±17.67	38.07^{ab}±0.84	37.23^{ab}±0.46
CD (at p≤ 0.05)	1.88	2.18	3.13	2.81
SEm (±)	0.63	0.73	1.05	0.94

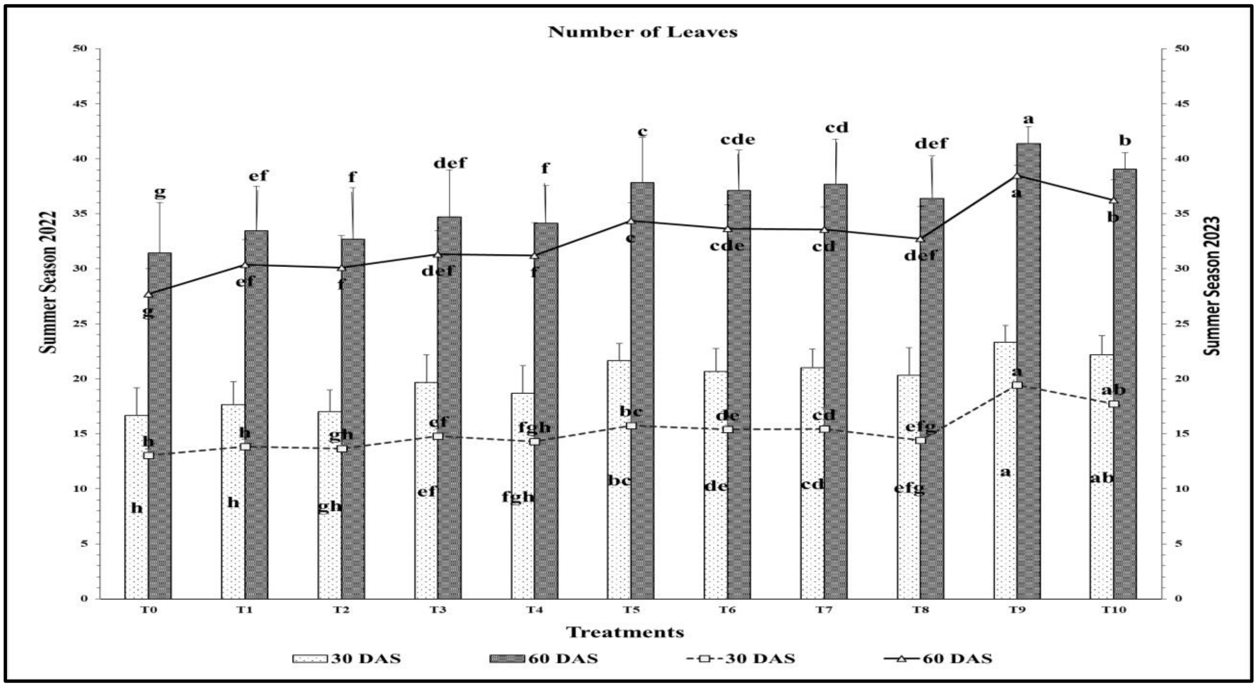


Figure 4.1.3.1a Effect of various treatments on number of leaves/plant of mung bean at 30 and 60 DAS during *Summer* season 2022-23

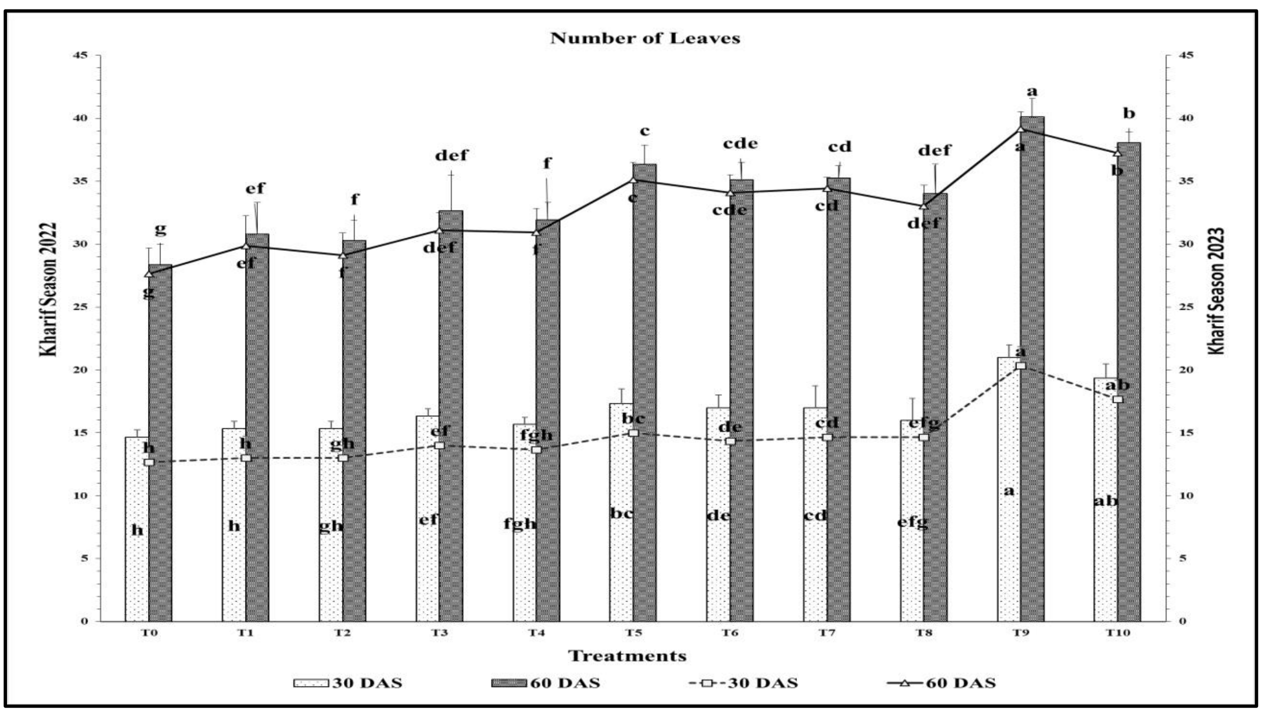


Figure 4.1.3.2a Effect of various treatments on number of leaves/plant of mung bean at 30 and 60 DAS during *Kharif* season 2022-23

4.1.4 Number of Branches (Plant^{-1})

The effect of priming in seeds with gibberellin, salicylic acid and micronutrient foliar application on number of branches was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The number of branches was documented at intervals of 30 and 60 (DAS). (Table 4.1.4.1, 4.1.4.2 and Figure 4.1.4.1a, 4.1.4.2a). During both 2022 and 2023, significant difference were observed in the percentage of branch numbers due to phytohormone priming and the foliar application of micronutrients. In *Summer* 2022 it was recorded that the maximum number of branches was found in T9 (6) followed by T10 (5.67) at 60 DAS. The lesser number of branches was found in control (T0) (3.33) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and found at par with single phytohormones priming i.e. T1 and T2. The percentage of number of branches was increased in T9 by 34.7% at 30 or 33.3% at 60 DAS when compared to the treatment T0. It was also observed that percentage of number of branches was lowest in control (T2) i.e. 22.9% and 39.8% at 30 and 60 DAS respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. In *Summer* 2023, it was recorded that maximum branches was found in T9 (5.83) followed by T10 (5.50) at 60 DAS. The minimum number of branches was found in control (T0) (3.33) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and found at par with single phytohormones priming in treatment T1 and T2. The percentage of branch numbers saw a significant increase in treatment T9 (combined foliar application of zinc and boron in gibberellin-primed seed plants), with raises of 49.6% and 42.9% at 30 and 60 days after sowing (DAS) respectively, in comparison to control T0. It was also observed that percentage of number of branches was lowest in treatment (T1) i.e. 78.2% and 60.1% at 30 and 60 DAS respectively when compared with treatment (T6). Overall, both *Summer*s of 2022 and 2023 demonstrated that treatments T9 and T10 consistently resulted in the highest number of branches. The control treatment T0 consistently had the lowest branch count, while treatment T9 showed the most significant percentage increase in branch numbers compared to the control.

Table 4.1.4.1 Effect of various treatments on number of branches/plant of mung bean at 30 and 60 DAS during *Summer* season 2022 and 2023

	Number of branches/plant *Summer* 2022 and *Summer* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	$2.50^{d}\pm0.00$	$1.70^{f}\pm0.00$	$3.33^{f}\pm0.50$	$3.33^{f}\pm0.29$
T1	$2.83^{cd}\pm0.29$	$2.03^{e}\pm0.06$	$4.33^{de}\pm0.29$	$4.33^{de}\pm0.29$
T2	$2.83^{cd}\pm0.29$	$2.00^{e}\pm0.00$	$4.00^{ef}\pm0.29$	$4.00^{e}\pm0.00$
T3	$3.17^{abc}\pm0.29$	$2.33^{d}\pm0.29$	$4.67^{cde}\pm0.29$	$4.67^{cd}\pm0.29$
T4	$2.83^{cd}\pm0.29$	$2.03^{e}\pm0.06$	$4.33^{de}\pm0.58$	$4.33^{de}\pm0.29$
T5	$3.83^{a}\pm0.29$	$3.03^{b}\pm0.06$	$5.67^{ab}\pm0.58$	$5.33^{ab}\pm0.29$
T6	$3.67^{ab}\pm0.58$	$3.03^{b}\pm0.06$	$5.33^{abc}\pm0.58$	$5.33^{ab}\pm0.29$
T7	$3.67^{ab}\pm0.58$	$3.03^{b}\pm0.06$	$5.33^{abc}\pm0.58$	$5.33^{ab}\pm0.29$
T8	$3.50^{ab}\pm0.00$	$2.70^{c}\pm0.00$	$5.00^{bcd}\pm0.00$	$5.00^{cd}\pm0.00$
T9	$3.83^{a}\pm0.29$	$3.37^{a}\pm0.23$	$6.00^{a}\pm0.00$	$5.83^{a}\pm0.29$
T10	$3.83^{a}\pm0.29$	$3.37^{a}\pm0.23$	$5.67^{ab}\pm0.58$	$5.50^{ab}\pm0.50$
CD (at p≤ 0.05)	0.6	0.24	0.84	0.51
SEm (±)	0.2	0.12	0.28	0.17

During the *Kharif* season of 2022, there was a significant increase in the percentage of branch numbers in treatment T10 (combined application of micronutrient (Zn, B) in form of foliar in salicylic acid-primed seed plants), with raises of 45.5% and 36.6% observed at 30 and 60 days after sowing (DAS) respectively, compared to control T0. It was also observed that percentage of number of branches was lowest in treatment (T4) i.e. 23.3% and 3.7% at 30, and 60 DAS respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023 it was recorded that the percentage branches number was increased in T10 by 55.7% at 30 and 31.1% at 60 and 60 DAS respectively when compared to the control (i.e. treatment T0). It was also observed that percentage of number of branches was lowest in control (T3) i.e. 12.7% and 18.8% at 30 and 60 DAS respectively when compared with treatment

(T5) i.e. foliar application of zinc in gibberellin primed seed plants. Overall, the *Kharif* season data from 2022 and 2023 indicates that treatments T10 and T5 were effective in increasing the number of branches, with T10 consistently showing the highest percentage increase in branch numbers compared to the control across both years. The control treatment T0 remained the lowest in terms of branch count, while other treatments like T8 also demonstrated improvements in branch count compared to their respective controls. Both the *Summer* and *Kharif* season crop of mung bean number of branches was slightly greater in *Summer* season as we compare to *Kharif* season, number of branches in the crop of *Summer* season was higher. When comparing the crops from 2022 to those from 2023, the 2022 crop exhibited a greater number of branches. Gibberellic acid encourages early and vigorous growth, resulting in an increased number of branches. A higher number of branches and leaves contributes to greater biomass. Additionally, more branches generally lead to more leaves, as each branch generates its own set of leaves. The results are supported by **Dass *et al.,* 2022; Kayata *et al.,* 2024; Selim *et al.,* 2023; Rashid *et al.,* 2024.** Effective nutrient uptake and utilization supported by Zn and B ensure that the additional branches contribute positively to the plant's fresh weight. Gibberellic acid also stimulates the growth of lateral buds while Zn and B provide the necessary support for these new branches and more robust early growth, setting the stage for increased branching. Similar results were given by **Bhatia *et al.,* 2022; Iqbal *et al.,* 2022; Zafar *et al.,* 2023.**

Table 4.1.4.2 Effect of various treatments on number of branches/plant of mung bean at 30 and 60 DAS during *Kharif* season 2022 and 2023

	Number of branchess/plant *Kharif* 2022 and *Kharif* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	2.00^{e}±0.00	1.33^{d}±0.29	3.17^{e}±0.29	3.00^{f} ±0.47
T1	2.33^{de}±0.29	2.00^{c}±0.00	4.00^{cd}±0.50	4.00^{ef}±0.00
T2	2.33^{de}±0.29	2.00^{c}±0.00	3.50^{de}±0.50	3.67^{e} ±0.00
T3	2.67^{cd}±0.29	2.33^{c}±0.29	4.33^{bcd}±0.29	4.33^{de}±0.58
T4	2.33^{de}±0.29	2.00^{bc}±0.00	4.17^{bcd}±0.29	4.00^{ef}±0.00
T5	3.33^{ab}±0.29	2.67^{ab}±0.29	4.83^{abc}±0.29	5.33^{ab}±0.29
T6	3.33^{ab}±0.29	2.67^{ab}±0.29	4.50^{bc}±0.50	5.00^{bc}±0.00
T7	3.33^{ab}±0.29	2.33^{bc}±0.29	4.67^{bc}±0.76	5.03^{bc}±0.45
T8	3.00^{bc}±0.00	2.33^{bc}±0.29	4.33^{bcd}±0.29	4.67^{cd}±0.25
T9	3.67^{a}±0.29	3.00^{a}±0.00	5.50^{a}±0.50	5.67^{a}±0.06
T10	3.67^{a}±0.29	3.00^{a}±0.00	5.00^{ab}±0.50	5.33^{ab}±0.29
CD (at p≤ 0.05)	0.44	0.4	0.81	0.52
SEm (±)	0.15	0.13	0.27	0.17

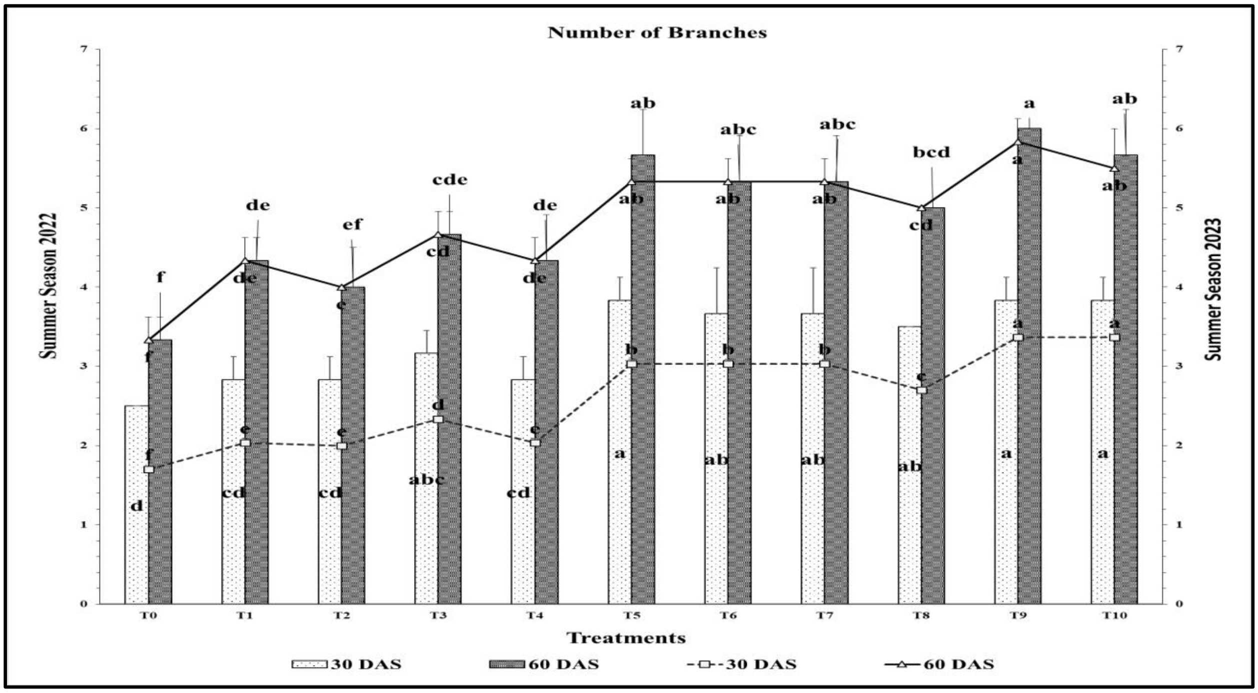


Figure 4.1.4.1a Effect of various treatments on number of branches/plant of mung bean at 30 and 60 DAS during *Summer* season 2022

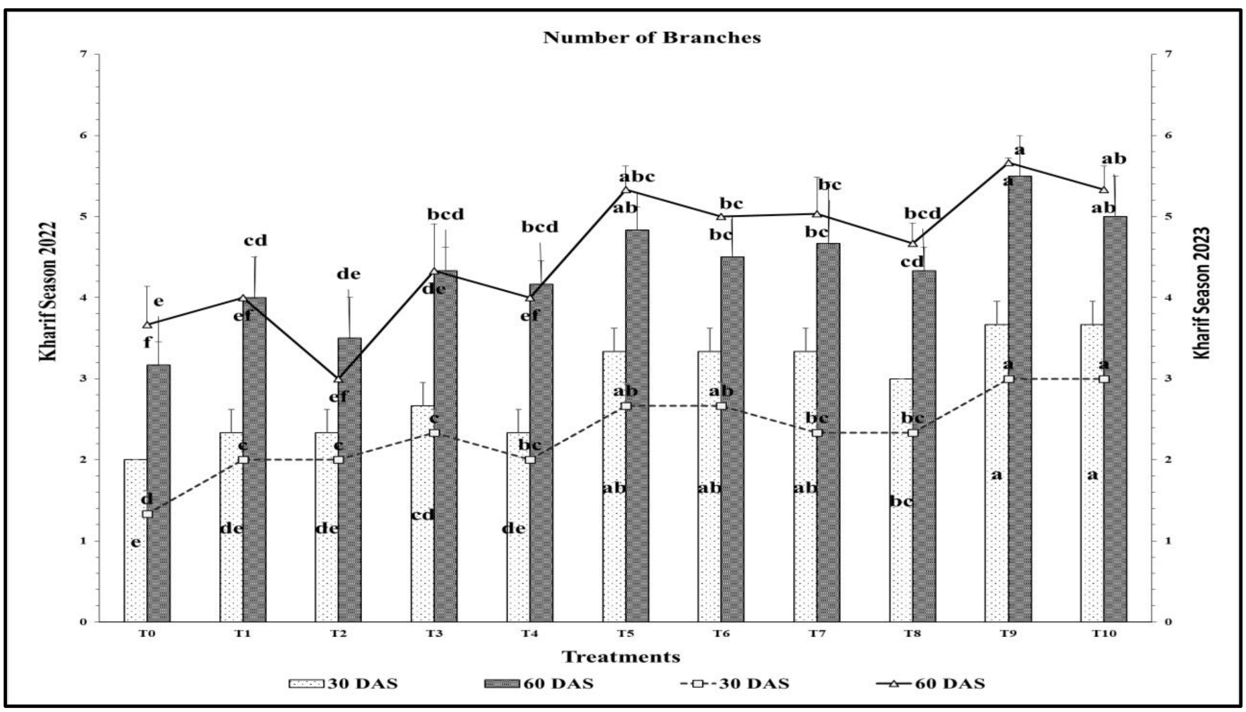


Figure 4.1.4.2a Effect of various treatments on number of branches/plant of mung bean at 30 and 60 DAS during *Kharif* season 2022

4.1.5 Fresh Weight (g)

The effect of seed priming with gibberellin, salicylic acid and foliar application of zinc and boron on fresh weight was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The fresh weight data was collected at intervals of 30 or 60 (DAS), as well as at harvest (Table 4.1.5.1, 4.1.5.2 and Figure 4.1.5.1aa Figure 4.1.5.2a). In 2022 and 2023, there was a significant difference in the percentage of fresh weight by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 recorded that the maximum fresh weight was found in T9 (135.33 g) followed by T10 (131.93 g) At harvest and fresh weight of treatment T9 At harvest was significantly maximum as compared with all other treatments and it was found at par with treatment T10. The minimum fresh weight was observed in the control (T0) at 89.23 g, which was significantly lower than the treatments involving priming with phytohormones and the combined foliar application of zinc and boron. However, it was comparable to the single phytohormone priming treatments, T1 (101.63 g) and T2 (96.57 g). The fresh weight in T9 increased by 56.4%, 30.7%, and 34.4% at the 30-day, 60-day intervals after sowing (DAS), and at harvest when compared to the control (T0). It was also observed that percentage of fresh weight was lowest in control (T2) i.e. 29%, 21.8% and 19.9% at 30, 60 and at harvest respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. In *Summer* 2023 it was recorded that the maximum fresh weight was found in T9 (133.83 g) followed by (T10) (130.07 g) at harvest and fresh weight of treatment T9 At harvest was significantly maximum as compared with other treatments and it was found at par with treatment T10. The minimum fresh weight was found in control (T0) (93.60 g) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and found at par with single phytohormones priming i.e. T1 (98.07 g) and T2 (95.17 g). The fresh weight percentage significantly increased in treatment T9 (combined foliar application of zinc and boron on gibberellin-primed seed plants) by 37.9%, 31.6%, and 30% at the 30-day and 60-day intervals after sowing (DAS), and at harvest, respectively, compared to treatment T0. Also, it was found that the treatment T7 enhanced the percentage of fresh weight by 12.4%, 7.2% and 12% at 30, 60 DAS intervals and At harvest when compared with treatment T3 (i.e. individual foliar application zinc). It was also observed that percentage of fresh weight was lowest in treatment (T1) i.e. 31.6%, 27.7% and 26.9% at 30, 60 and at harvest respectively when compared with treatment (T6). Overall, both

*Summer*s of 2022 and 2023 showed that treatments T9 and T10 consistently resulted in the highest fresh weights. The control treatment T0 consistently had the lowest fresh weight, while treatment T9 showed the most significant percentage increase in fresh weight compared to the control across both years.

Table 4.1.5.1 Effect of various treatments on fresh weight (g) of mung bean at 30, 60 and at harvest during *Summer* season 2022 and 2023

	Fresh Weight (g) *Summer* 2022 and *Summer* 2023					
	30DAS		**60DAS**		**At Harvest**	
Treatments	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
T0	10.62^{f}±2.35	10.8^{f}±1.51	83.17^{h}±2.69	77.96^{e}±5.38	89.23^{g}±9.60	93.6^{g}±3.65
T1	14.21^{def}±2.49	12.67^{def}±0.41	88.63^{fgh}±7.32	84.76^{de}±6.91	101.63^{fg}±4.7	98.07^{fg}±3.80
T2	12.96^{ef}±2.43	11.98^{ef}±1.77	85.97^{gh}±3.55	81.27^{e}±6.03	96.57^{fg}±8.92	95.17^{fg}±3.15
T3	15.52^{cde}±1.44	13.03^{cdef}±0.30	95.4^{ef}±3.15	88.6^{de}±4.74	108.47^{def}±13.6	107.37^{e}±3.59
T4	14.75^{cde}±.090	12.89^{def}±1.58	91.5^{fg}±3.05	86.2^{de}±5.21	104.43^{ef}±8.90	102.3^{ef}±4.03
T5	18.8^{bc}±1.65	15.63^{abc}±1.25	111.4^{bc}±3.61	103.18^{bc}±8.21	125.1^{abc}±6.77	127.6^{ab}±5.36
T6	17.45^{bcd}±2.02	14.21^{bcde}±1.85	104.67^{cd}±4.3	99.54^{bc}±5.06	118.68^{bcd}±4.6	118.77^{cd}±4.1
T7	18.26^{bcd}±1.92	14.87^{abcd}±0.35	110^{bc}±3.60	95.47^{cd} ±4.12	120.53^{bcd}±5.4	122^{bc}±4.51
T8	16.4^{cde}±2.76	13.74^{cde}±1.27	101.1^{de}±3.70	88.23^{de} ±5.98	115.53^{cde}±3.9	114.43^{d}±2.06
T9	24.33^{a}±3.07	17.38^{a}±2.59	119.93^{a}±4.85	114.04^{a}±5.70	135.33^{a}±5.45	133.83^{a}±4.49
T10	20.83^{ab}±2.48	16.47^{ab}±0.33	115.67^{ab}±3.7	108.53^{ab}±4.46	131.93^{ab}±5.6	130.07^{a}±5.37
CD (at p≤ 0.05)	3.97	2.34	8.12	10.21	14.5	7.03
SEm (±)	1.33	0.78	2.23	2.69	4.43	2.63

In the *Kharif* season of 2022, treatment T10 (zinc (Zn) and boron (B) application in salicylic acid-primed seed plants) resulted in a significant increase in fresh weight by 45.5%, 34.3%, and 34.7% at 30 days, 60 days after sowing (DAS), and At harvest, respectively, compared to the treatment (T0). Also, it was found that the treatment T5 enhanced the percentage of fresh weight by 22.5%, 19.5% and 21.2% at 30-days, 60-days and at harvest respectively when compared with treatment T1 (i.e. individual application of gibberellin primed seed plants). It was also observed that percentage of fresh weight was lowest in treatment (T4) i.e. 9.2%, 10.7% and 10.1% at 30, 60 and at harvest respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In the *Kharif* season of 2023, it was recorded that treatment T10 showed an increase in fresh weight by 49.2%, 39.8%, and 35% at 30-DAS, 60-DAS, and harvest, respectively, compared to the control (T0). It was also observed that percentage of fresh weight was lowest in control (T3) i.e. 22.3%, 18% and 15.8% at 30, 60 and at harvest respectively when compared with treatment (T5) i.e. foliar application of zinc in gibberellin primed seed plants.. Overall, the *Kharif* seasons of 2022 and 2023 indicated that treatments T10 and T5 were effective in increasing fresh weight, with T10 consistently showing the highest percentage increase in fresh weight compared to the control across both years. The control treatment T0 remained the lowest in fresh weight, while other treatments like T8 also demonstrated improvements in fresh weight compared to their respective controls. Both the *Summer* and *Kharif* season crop of mung bean fresh weight was slightly greater in *Summer* season as we compare to *Kharif* season, fresh weight in the crop of *Summer* season was higher. Comparing the crops from 2022 to those from 2023, the fresh weight of the 2022 crop was superior. The combined application led to more vigorous vegetative growth, resulting in a higher fresh weight due to increased biomass accumulation in leaves, stems, and roots. GA_3 contributed to the higher fresh weight by promoting enhanced cell division and elongation, while foliar application of micronutrients facilitated the transport of sugars and nutrients within the plant. The results are supported by **Fayed *et al.,* 2020; Zafar *et al.,* 2023; Adsul *et al.*, 2020**. Improving overall growth directly boosts biomass accumulation in the plant, which is responsible for increasing fresh weight. Taller plants usually have a larger leaf area, enhancing their capacity to capture light and perform photosynthesis. The products of photosynthesis (sugars and other organic compounds) contribute to biomass accumulation, reflected in higher fresh weight. These findings align with **Ouddus *et al.,* 2020; Dass *et al.,* 2022; Thapa *et al.,* 2021.**

Table 4.1.5.2 Effect of various treatments on fresh weight (g) of mung bean at 30, 60 and at harvest during *Kharif* season 2022 and 2023

	Fresh Weight (g) *Kharif* 2022 and *Kharif* 2023					
	30DAS		60DAS		At Harvest	
Treatments	2022	2023	2022	2023	2022	2023
T0	12.22^{f}±2.36	6.97^{f}±1.89	69.16^{e}±5.39	62.93^{h}±3.10	84.03^{g}±4.45	77.17^{j}±3.01
T1	15.81^{def}±2.49	8.17^{ef}±1.20	75.96^{de}±11.87	70.17^{gh}±2.40	96.43^{ef}±4.71	84.94^{gh}±2.70
T2	14.56^{ef}±2.44	7.47^{ef}±1.29	72.47^{de}±10.48	67.00^{h}±3.34	91.37^{fg}±8.93	81.57^{hi}±2.78
T3	17.12^{cde}±1.45	9.77^{de}±1.37	79.8^{cde}±11.20	79.57^{ef}±4.61	103.27^{de}±6.52	93.27^{ef}±4.51
T4	16.35^{cde}±0.90	9.13^{def}±1.10	77.40^{cde}±5.21	75.05^{fg}±4.46	99.23^{ef}±8.90	88.91^{fg}±4.34
T5	20.40^{bc}±1.65	12.57^{bc}±1.38	94.38^{ab}±8.21	97.00^{b}±5.70	119.9^{abc}±6.77	110.83^{b}±5.75
T6	19.05^{bcd}±2.03	10.9^{cd}±1.05	90.74^{bc}±5.06	87.31^{cd}±5.79	113.48^{cd}±4.62	101.27^{cd}±5.80
T7	19.86^{bcd}±1.93	11.2^{cd}±1.11	79.43^{cde}±4.12	91.92^{bc}±2.77	115.33^{bc}±5.48	106.1^{bc}±2.91
T8	18.00^{cde}±2.76	10.6^{cd}±1.28	86.67^{bcd}±5.98	83.37^{de}±3.46	110.33^{cd}±3.92	97.77^{de}±3.11
T9	25.93^{a}±3.08	15.02^{a}±1.51	105.24^{a}±5.70	110.27^{a}±5.02	128.63^{a}±4.60	124.33^{a}±5.22
T10	22.43^{ab}±2.49	13.73^{ab}±0.97	99.73^{ab}±4.46	104.57^{a}±3.41	124.87^{ab}±5.37	118.8^{a}±3.25
CD (at p≤ 0.05)	3.97	1.78	10.21	7.21	10.89	7.13
SEm (±)	1.33	0.6	3.43	2.42	3.66	2.4

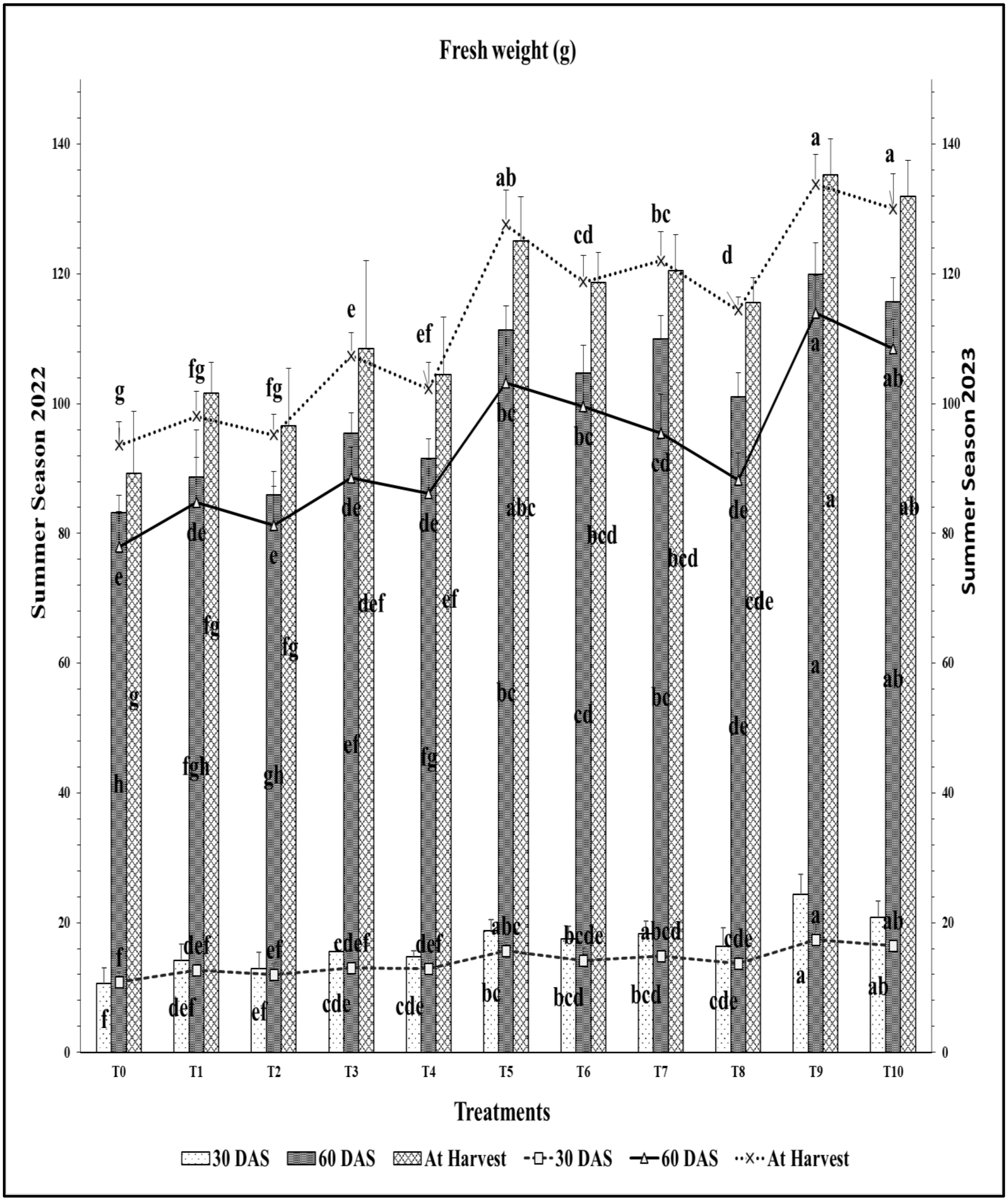


Figure 4.1.5.1a Effect of various treatments on fresh weight (g) of mung bean at 30, 60 and at harvest during *Summer* season 2022-23

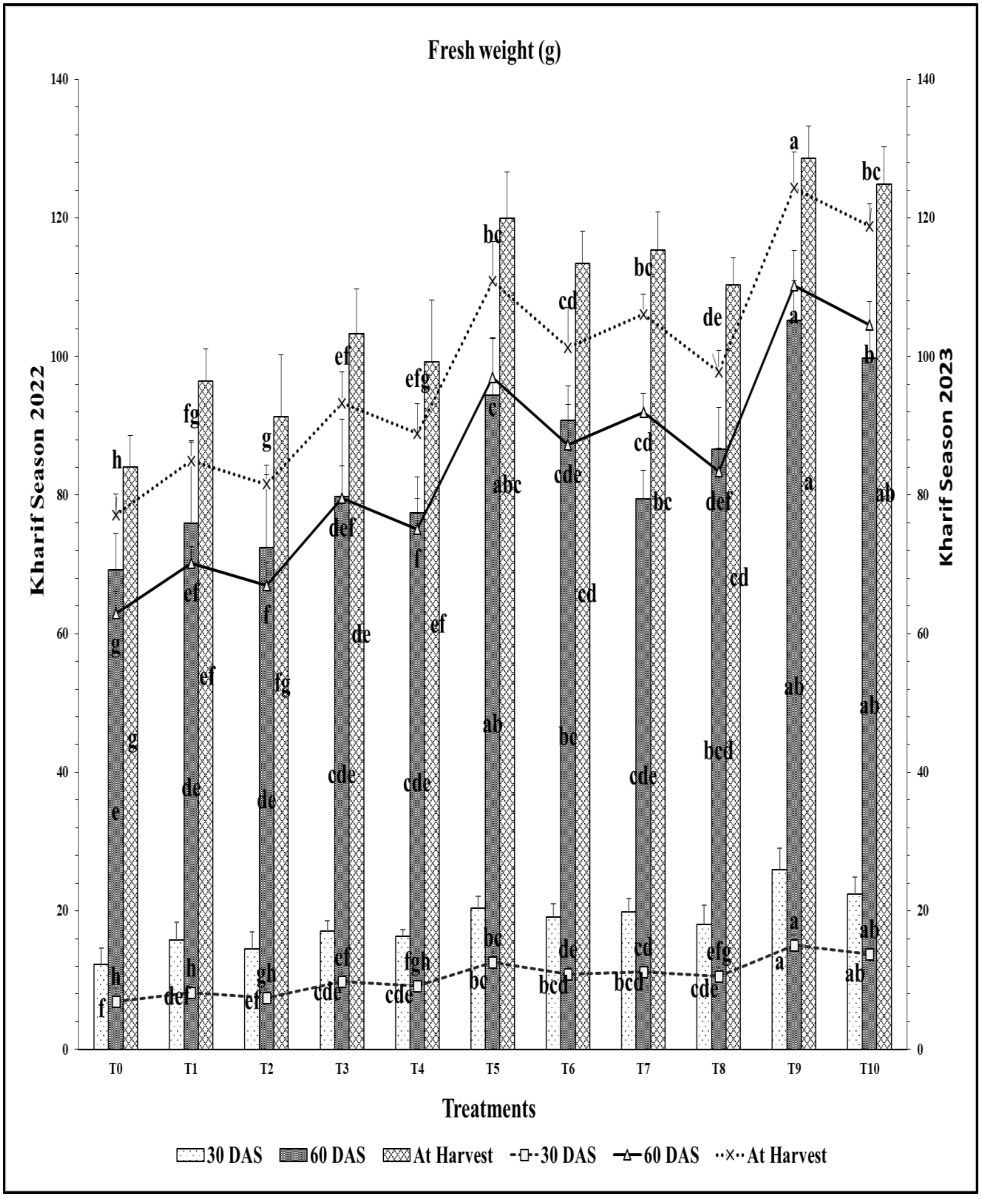


Figure 4.1.5.2a Effect of various treatments on fresh weight (g) of mung bean at 30, 60 and at harvest during *Kharif* season 2022-23

4.1.6 Dry Weight (g)

The effect of seed priming with gibberellin, salicylic acid and foliar application of zinc and boron on dry weight was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. Dry weight observation was taken at 30-day, 60-day intervals, and at harvest. (Table 4.1.6.1, 4.1.6.2 and Figure 4.1.6.1a, Figure 4.1.6.2a). In 2022 and 2023, there was a significant difference in the (%) of dry weight by phytohormones priming and foliar application of micronutrients. In *Summer* 2022, it was recorded that the maximum dry weight was found in T9 (45.74 g) followed by T10 (42.56 g) At harvest and dry weight of treatment T9 At harvest was significantly maximum as compared with all other treatments and it was found at par with treatment T10. The control group (T0) exhibited the lowest dry weight at 27.86 g, significantly lower than treatments involving phytohormone priming and the combined foliar application of zinc and boron, but comparable to single phytohormone priming treatments, such as T1 (29.35 g) and T2 (28.44 g). Conversely, the percentage of dry weight increased in treatment T9 by 39.6%, 46.6%, and 39% at 30-days, 60-days after sowing (DAS), and at harvest, respectively, compared to treatment T0. It was also detected that percentage of dry weight was lowest in control (T2) i.e. 29%, 32.9% and 27.7% at 30, 60 and at harvest respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. Similarly, it was found that the treatment T6 (i.e. boron (B) foliar application in Gibberellin primed seed plants) enhanced the percentage of dry weight by 12.4%, 16.7% and 17% at 30, 60 DAS interval and at harvest when compared with treatment T4 i.e. individual foliar application of boron. In *Summer* 2023 it was recorded that the maximum dry weight was found in T9 (39.70 g) followed by (T10) (38.59 g) at harvest and dry weight of treatment T9 At harvest was significantly maximum as compared with other treatments and it was found at par with treatment T10. The minimum dry weight was found in control (T0) (27.15 g) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and found at par with single phytohormones priming i.e. T1 (28.51 g) and T2 (27.32 g). The percentage of dry weight was significantly increased in treatment T9 (i.e. combined foliar application of Zinc and boron in gibberellin primed seed plants) 37.8%, 30.9% and 44.3% at 30, 60-DAS intervals and at harvest when compared to control (T0). It was also recorded that the percentage of dry weight was lowest in treatment (T1) i.e. 31.4%, 26.9% and 27.4% at 30, 60 and at harvest respectively when compared with treatment (T6). Overall, both

*Summer*s of 2022 and 2023 demonstrated that treatments T9 and T10 consistently resulted in the highest dry weights. The control treatment T0 consistently showed the lowest dry weight, while treatment T9 showed the most significant percentage enhance in dry weight compared to the treatment (T0) control in both years.

Table 4.1.6.1 Effect of various treatments on dry weight (g) of mung bean at 30, 60 and at harvest during *Summer* season 2022 and 2023

	Dry weight (g) *Summer* 2022 and *Summer* 2023					
	30DAS		**60DAS**		**at Harvest**	
Treatments	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
T0	4.37^{e}±0.86	3.18^{f}±0.45	19.74^{e}±0.84	21.07^{h}±1.46	27.94^{h}±1.18	27.53^{e}±1.08
T1	5.66^{cde}±1.26	3.73^{def}±0.12	21.45^{e}±3.82	22.91^{fg}±3.21	29.35^{gh}±1.22	28.84^{e}±1.12
T2	5.14^{de}±0.90	3.52^{ef}±0.52	20.61^{e}±1.11	21.96^{gh}±2.83	28.44^{h}±1.02	27.99^{e}±0.93
T3	5.77^{bcd}±0.45	3.83^{cdef}±0.09	24.53^{d}±0.95	23.85^{ef}±1.11	31.87^{f}±1.31	31.58^{d}±1.06
T4	5.58^{cde}±0.32	3.79^{def}±0.47	23.44^{d}±0.99	23.3^{fg}±1.41	31.01^{fg}±1.70	30.09^{d}±1.19
T5	6.68^{abc}±0.52	4.6^{abc}±0.37	31.81^{b}±1.13	27.89^{bc}±2.22	40.2^{c}±1.68	36.53^{b}±1.58
T6	6.37^{abcd}±0.45	4.18^{bcde}±0.54	28.13^{c}±1.13	26.94^{cd}±3.04	37.34^{d}±1.32	34.93^{c}±1.21
T7	6.62^{abc}±0.58	4.37^{abcd}±0.10	30.71^{b}±1.35	26.9^{cd}±1.37	39.35^{c}±1.46	35.88^{b}±1.33
T8	6.1^{abcd}±0.96	4.04^{cde}±0.37	27.34^{c}±1.16	25.8^{de}±1.62	35.54^{e}±1.23	33.66^{c}±0.61
T9	7.23^{a}±0.90	5.11^{a}±0.76	36.97^{a}±1.52	30.82^{a}±1.54	44.15^{a}±1.98	39.36^{a}±1.35
T10	7.1^{ab}±0.34	4.85^{ab}±0.10	35.21^{a}±1.17	29.33^{ab}±1.21	42.56^{b}±1.81	38.25^{a}±1.58
CD (at p≤ 0.05)	1.26	0.69	1.72	1.64	1.79	1.27
SEm (±)	0.42	0.23	0.58	0.55	0.6	0.42

In *Kharif* 2022 the percentage of dry weight was significantly increased in treatment T10 (Zinc (Zn) and boron (B) combined foliar application in salicylic acid primed seed plants) 32.3%, 33.4% and 32.1% at 30-days, 60-DAS intervals and at harvest when compared to treatment (T0). Similarly, it was found that the treatment T5 enhanced the percentage of dry weight by 16.8%, 19.5% and 16.4% at 30, 60 DAS intervals and at harvest when compared with treatment T1 (i.e. individual application of gibberellin primed seed plants). It was also observed that the percentage of dry weight was lowest in treatment (T4) i.e. 8.9%, 9.0% and 11.3% at 30, 60 and at harvest respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023, it was recorded that the percentage of dry weight was increased in T10 by 49.3%, 38.7% and 32.7% at 30, 60 DAS and at harvest respectively as compared to the control T0. It also observed that percentage (%) of dry weight was lowest in control (T3) i.e. 18.5%, 17.4% and 15.7% at 30, 60 and at harvest respectively when compared with treatment (T5) i.e. foliar application of zinc in gibberellin primed seed plants. Overall, the *Kharif* seasons of 2022 and 2023 showed that treatments T10 and T5 were effective in increasing dry weight, with T10 consistently showing the highest percentage increase in dry weight compared to the control in both years. The control treatment T0 consistently had the lowest dry weight, while other treatments like T8 demonstrated improvements in dry weight compared to their respective controls. The dry weight of the mung bean crop was slightly higher in the *Summer* season compared to the *Kharif* season, indicating that the *Summer* crop had a greater dry weight overall. When comparing the crops from 2022 and 2023, the crop grown in 2022 performed better in terms of dry weight than the one grown in 2023. Adequate water and nutrient supply are crucial for ensuring that increased plant height corresponds to increased fresh weight, as they help the plant maintain turgor and overall health. Timely applications of nutrients ensure that rapidly growing plants, especially those primed with GA_3, have enough resources to sustain their growth. GA_3 priming increases plant height, which, when supported by sufficient nutrients (Zn and B), relates to higher dry weight **(Iqbal *et al.,* 2023; Swain *et al.,* 2023).** Then the taller plants often have a higher dry weight due to more extensive biomass. Phytohormones application (GA_3) induced early and vigorous growth, coupled with Zn and B-supported physiological functions, can significantly increase dry weight. These results are corroborated with **Haider *et al.,* 2020; Kumar *et al.,* 2020; Zafar *et al.,* 2023; Thapa *et al.,* 2021.**

Table 4.1.6.2 Effect of various treatments on dry weight (g) of mung bean at 30, 60 and at harvest during *Kharif* season 2022 and 2023

	Dry weight (g) *Kharif* 2022 and *Kharif* 2023					
	30DAS		60DAS		at Harvest	
Treatments	2022	2023	2022	2023	2022	2023
T0	3.57^{d}±0.21	2.32^{f}±0.63	20.34^{h}±1.58	17.32^{i}±0.88	24.72^{f}±2.83	22.13^{i}±1.07
T1	3.97^{cd}±0.15	2.72^{ef}±0.40	22.34^{fg}±3.49	19.42^{gh}±0.72	28.36^{de}±3.61	23.44^{hi}±1.11
T2	3.93^{cd}±0.15	2.49^{ef}±0.43	21.31^{gh}±3.08	18.6^{hi}±0.79	26.87^{e}±2.63	22.59^{i}±0.92
T3	4.12^{bcd}±0.29	3.26^{cde}±0.46	23.47^{f}±3.29	21.94^{f}±1.25	30.37^{c}±4.01	26.18^{f}±1.05
T4	4.00^{cd}±0.215	3.04^{def}±0.37	22.76^{fg}±1.53	20.76^{fg}±1.30	29.19^{cd}±2.62	24.69^{g}±1.18
T5	4.77^{ab}±0.42	4^{bc}±0.36	27.76^{c}±2.41	26.01^{c}±1.63	33.92^{b}±1.61	31.13^{bc}±1.57
T6	4.37^{bc}±0.31	3.63^{cd}±0.35	25.49^{de}±1.7	24.17^{de}±1.59	32.45^{b}±1.15	29.53^{de}±1.20
T7	4.43^{bc}±0.35	3.73^{cd}±0.37	26.69^{cd}±1.49	25.61^{cd}±0.71	33.38^{b}±1.36	30.48^{cd}±1.32
T8	4.39^{bc}±0.60	3.53^{cd}±0.43	25.01^{e}±1.12	23.66^{e}±1.21	33.27^{b}±1.99	28.26^{e}±0.60
T9	5.37^{a}±0.56	5.01^{a}±0.50	30.95^{a}±1.68	30.82^{a}±1.49	37.83^{a}±1.35	33.96^{a}±1.35
T10	5.27^{a}±0.31	4.58^{ab}±0.32	29.33^{b}±1.31	28.26^{b}±0.90	36.73^{a}±1.58	32.85^{ab}±0.93
CD (at $p \leq 0.05$)	0.55	0.53	1.53	1.54	1.74	1.84
SEm (±)	0.19	0.18	0.51	0.52	0.59	0.61

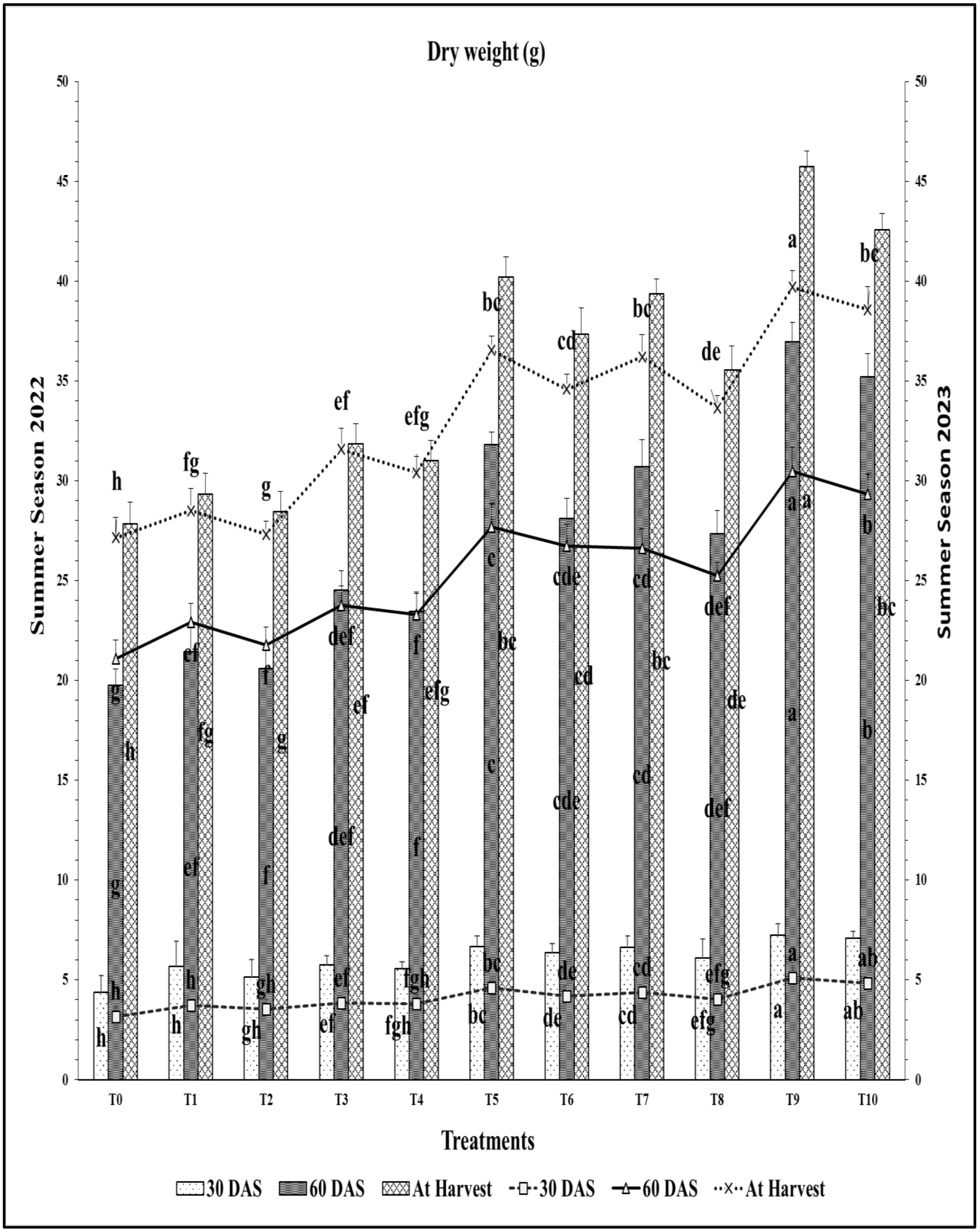


Figure 4.1.6.1a Effect of various treatments on dry weight (g) of mung bean at 30, 60 and at harvest during *Summer* season 2022-23

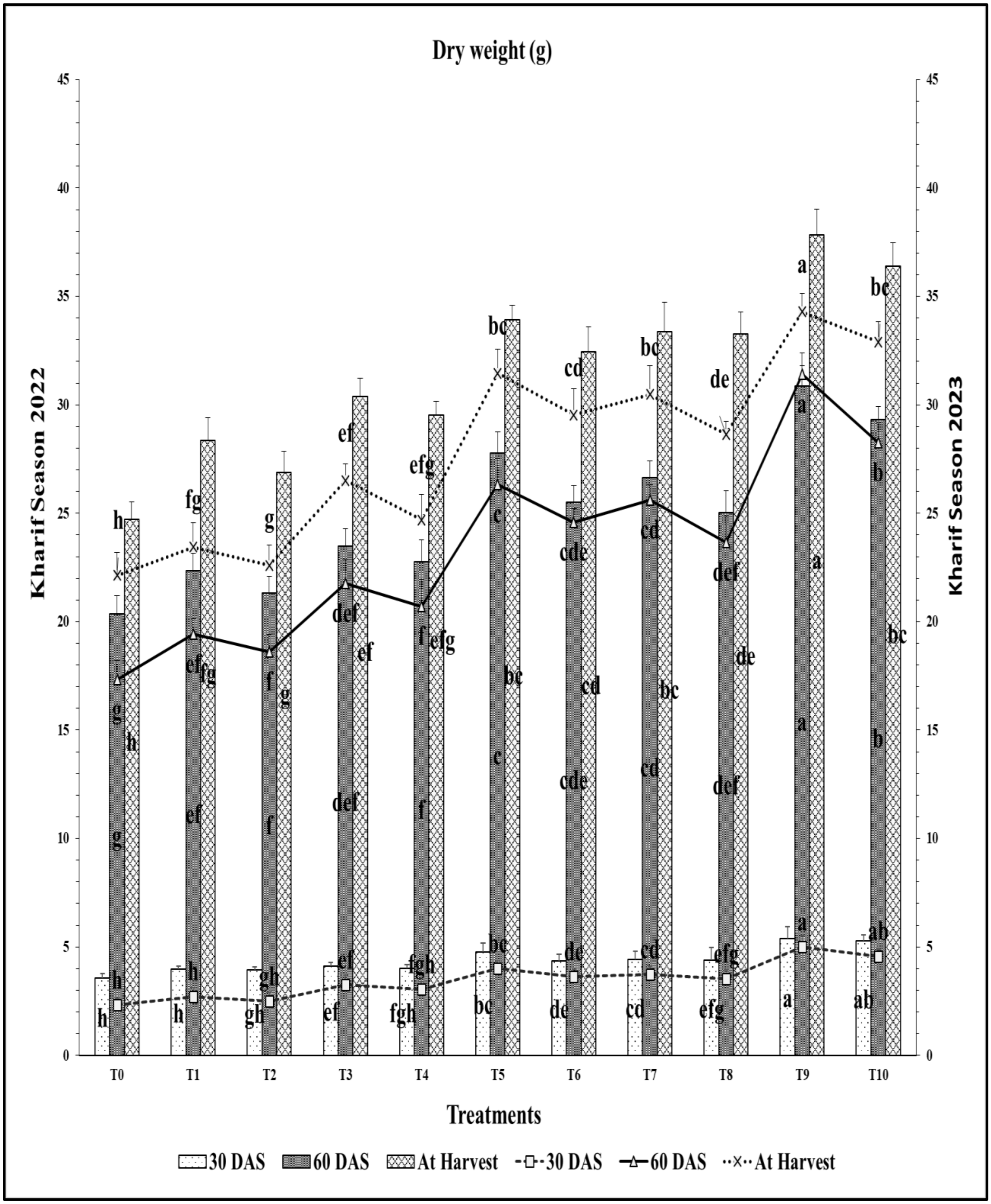


Figure 4.1.6.2a Effect of various treatments on dry weight (g) of mung bean at 30, 60 and at harvest during *Kharif* season 2022-23

4.1.7 Root Length (cm)

The effect of seed priming with gibberellin, salicylic acid or foliar application of zinc and boron on root length was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of root length was recorded at 30 and 60 DAS (Table 4.1.7.1, 4.1.7.2 and Figure 4.1.7.1a, 4.1.7.2a,). In 2022 and 2023, there was a significant difference in the percentage of root length by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that the maximum root length was found in T9 (31.17 cm) followed by T10 (29.33 cm) at 60 DAS. The minimum root length was found in control (T0) (20.33 cm) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and found at par with single phytohormones priming i.e. T1 and T2. The length of root percentage (%) was increased in T9 by 36.1% at 30-DAS and 34.8% at 60-DAS respectively as compared to the treatment T0. It was also observed that percentage of root length was lowest in control (T2) i.e. 13.6% and 23.5% at 30 and 60 DAS respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. In *Summer* 2023 the percentage of root length was significantly increased in treatment T9 (i.e. combined micronutrient (Zn+B) foliar application in gibberellin primed seed plants) 43.6% at 30-DAS and 34.5% at 60-DAS respectively as compared to control (T0). It was also observed that percentage of root length was lowest in treatment (T1) i.e. 39.4% and 27.3% at 30 and 60 DAS respectively when compared with treatment (T6). The *Summer* seasons of 2022 and 2023 showed that treatments T9 and T10 consistently resulted in the greatest root length, with T9 showing the highest percentage increases in both years. The control treatment (T0) consistently showed the lowest root length, while other treatments such as T6 and T7 demonstrated improvements compared to their respective controls.

Table 4.1.7.1 Effect of various treatments on root length (cm) of mung bean at 30 and 60 DAS during *Summer* season 2022 and 2023

	Root length *Summer* 2022 and *Summer* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	15.33^{e}±1.76	11.00^{e}±1.32	20.33^{e}±3.01	18.33^{f}±3.01
T1	17.00^{cd}±2.00	12.50^{de}±1.50	22.33^{de}±2.75	20.00^{ef}±2.50
T2	17.00^{cd}±1.32	12.00^{de}±0.50	21.67^{de}±1.15	19.67^{ef}±1.76
T3	18.00^{bcd}±2.29	13.63^{cd}±1.04	25.33^{bcd}±2.25	21.33^{cdef}±1.76
T4	17.50^{cd}±2.50	12.87^{de}±1.03	24.67^{cd}±1.26	20.83^{def}±1.44
T5	19.83^{bc}±2.25	16.17^{b}±1.04	28.67^{abc}±2.57	25.33^{abc}±2.25
T6	19.03^{cd}±1.84	15.33^{bc}±0.76	26.67^{bc}±1.89	23.33^{bcde}±2.25
T7	19.67^{bc}±1.04	16.00^{b}±1.00	28.33^{abc}±2.52	24.67^{abcd}±2.02
T8	19.67^{bc}±2.02	15.33^{bc}±1.15	28.00^{abc}±2.29	23.33^{bcde}±2.52
T9	24.00^{a}±2.29	19.50^{a}±1.80	31.17^{a}±2.52	28.00^{a}±2.50
T10	21.33^{ab}±1.04	18.50^{a}±1.50	29.33^{ab}±1.15	26.00^{ab}±1.32
CD (at p≤ 0.05)	3.18	2.08	3.72	3.86
SEm (±)	1.07	0.7	1.26	1.29

In *Kharif* 2022 the percentage of root length was significantly increased in treatment T10 (i.e. combined foliar application of Zinc (Zn) and boron (b) in salicylic acid primed seed plants) 37.5% at 30-DAS and 27.9% at 60-DAS when compared to control (T0). Similarly, it was found that the treatment T5 enhanced the percentage of root length by 22.3% and 16.1% at 30 and 60 DAS respectively when compared with treatment T1 (i.e. individual application of gibberellin primed seed plants). It was also observed that percentage of root length was lowest in treatment (T4) i.e. 11.8% and 10.1% at 30, and 60 DAS respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023, it was recorded that the maximum root length was found in T9 (25.70 cm) followed by T10 (23.70 cm) at 60 DAS. The minimum root length of plant was found in control (T0) (16.03 cm) i.e. significantly lower than priming with phytohormone and combined foliar application of zinc and boron and found at par with single phytohormones priming i.e. T1 and T2. The percentage (%) of root length was increased in T10 by 35.8% and 32.4% at 30 and 60 DAS respectively as compared to the control T0. It was also observed that percentage of root length was lowest in control (T3) i.e. 13.7% and 17.4% at 30 and 60 DAS respectively when compared with treatment (T5) i.e. foliar application of zinc in gibberellin primed seed plants. The *Kharif* seasons of 2022 and 2023 demonstrated that treatments T9 and T10 were effective in increasing root length, with T10 showing the highest percentage increase in root length compared to the treatment (T0) control in both years. The control treatment (T0) consistently had the lowest root length, while treatments such as T5 and T8 showed significant improvements in root length compared to their respective controls. Both the *Summer* and *Kharif* season crop of mung bean root length was slightly greater in *Summer* season as we compare to *Kharif* season, root length in the crop of *Summer* season was higher. As we compare both the 2022 and 2023 year crops, root length of crop growing in 2022 year performs well as compare to crop grows in 2023 seasons. Seeds treated with GA show faster and more vigorous early root growth, which is essential for effective nutrient and water uptake. Zinc (Zn) is important for the synthesis of auxin, a plant hormone that controls root growth. Zn activates enzymes that play a key role in root development and growth. Longer roots can reach deeper soil layers, enhancing water and nutrient absorption. The results agree with **Mahmud *et al.,* 2020; Fatima *et al.,* 2023; Sabagh *et al.,* 2021; Kohli *et al.,* 2023.** SA can enhance the plant's tolerance to biotic and abiotic stresses, which can positively affect root development. Longer roots can access more nutrients, supporting the growth of more leaves. Enhanced root systems lead to better overall plant health and vigor, resulting in more leaves. Strong root systems provide better anchorage, allowing the plant to grow taller without lodging. The results are supported by **Taher *et al.,* 2021; Zulfiqar *et al.,* 2022; Ejigu *et al.,* 2021.**

Table 4.1.7.2 Effect of various treatments on root length (cm) of mung bean at 30 and 60 DAS during *Kharif* season 2022 and 2023

	Root length *Kharif* 2022 and *Kharif* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	12.50^{e}±1.32	8.67^{e}±1.26	19.83^{d}±2.57	16.03^{f}±3.01
T1	14.50^{de}±0.50	10.00^{de}±1.32	21.67^{cd}±2.08	17.7^{ef}±2.50
T2	13.50^{de}±1.32	10.33^{cde}±1.53	20.50^{d}±2.50	17.37^{ef}±1.76
T3	15.83^{cd}±1.041	11.50^{bcd}±1.32	22.83^{bcd}±3.25	19.03^{cdef}±1.76
T4	15.00^{cd}±1.50	11.67^{bcd}±1.53	22.33^{bcd}±3.40	18.53^{def}±1.44
T5	18.67^{ab}±1.89	13.33^{b}±1.26	25.83^{abc}±2.84	23.03^{abc}±2.25
T6	17.17^{bc}±1.04	12.67^{bc}±0.76	24.17^{bcd}±1.76	21.03^{bcde}±2.25
T7	17.33^{bc}±1.25	13.00^{b}±1.50	24.67^{bcd}±3.06	22.37^{abc}±2.02
T8	17.00^{bc}±1.50	12.67^{bc}±1.61	24.83^{bcd}±2.25	21.03^{bcde}±2.52
T9	20.83^{a}±1.25	16.00^{a}±1.80	30.00^{a}±3.28	25.70^{a}±2.50
T10	20.00^{a}±1.50	13.50^{b}±1.00	27.5^{ab}±2.50	23.70^{ab}±1.32
CD (at p≤ 0.05)	2.21	2.18	4.1	3.86
SEm (±)	0.75	0.74	1.38	1.30

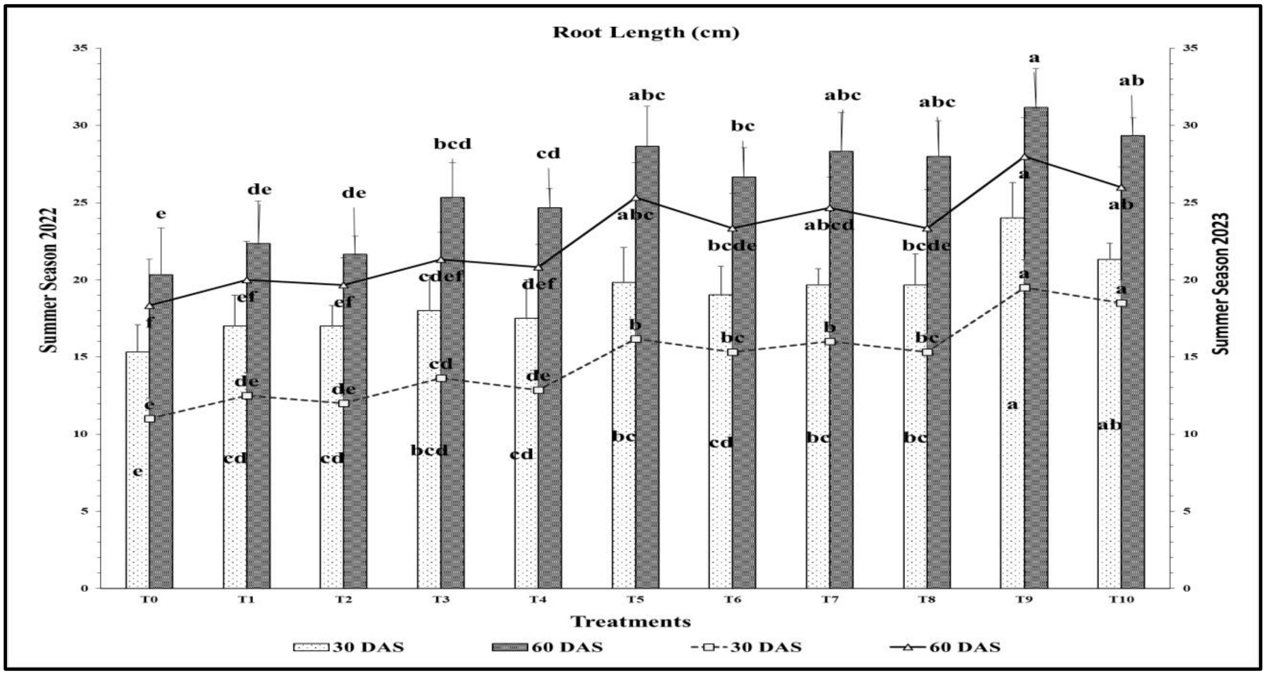


Figure 4.1.7.1a Effect of various treatments on root length (cm) of mung bean at 30 and 60 DAS during *Summer* season 2022-23

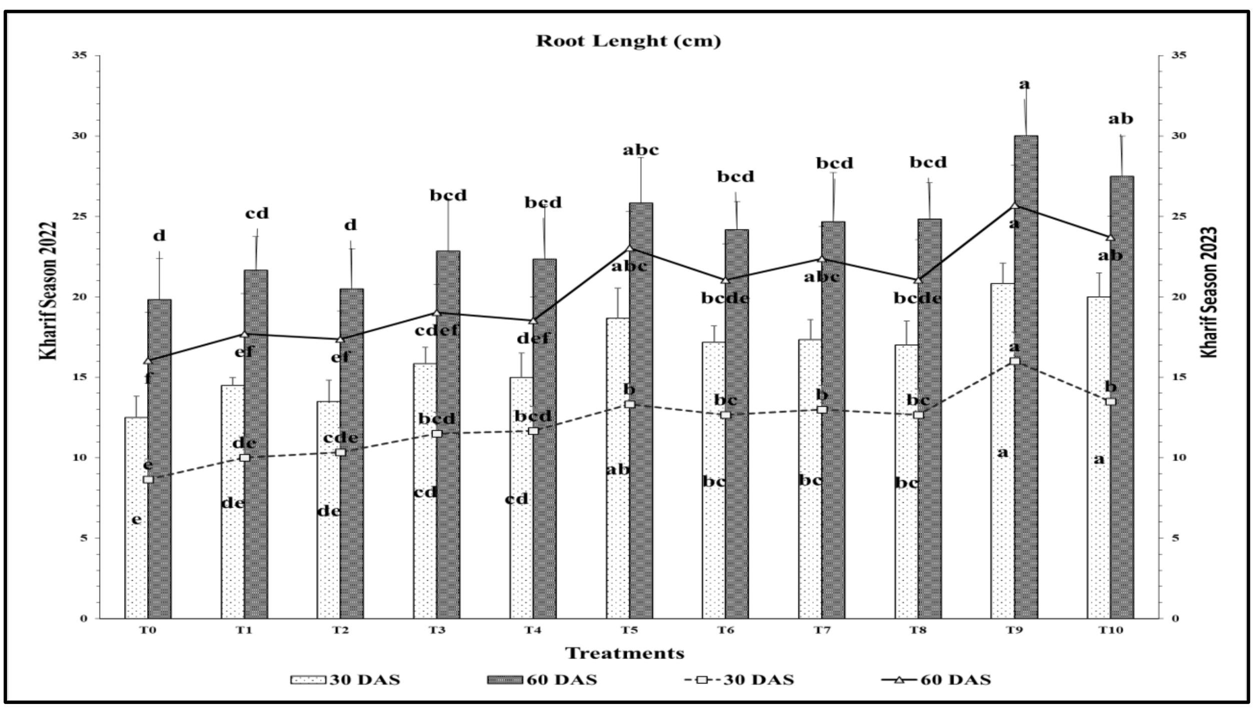


Figure 4.1.7.2a Effect of various treatments on root length (cm) of mung bean at 30 and 60 DAS during *Kharif* season 2022-23

4.1.8 Number of Nodules ($Plant^{-1}$)

The effect of priming seeds with gibberellin, salicylic acid and micronutrient foliar application on number of nodules was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of number of nodules was recorded at 30 and 60 DAS (Table 4.1.8.1, 4.1.8.2 and Figure 4.1.8.1a or 4.1.8.2a figure. In 2022 and 2023, there was a significant difference in the percentage of number of nodules by phytohormones priming and foliar application of micronutrients. In *Summer* 2022, it was recorded that the maximum number of nodules was found in T9 (44.33) followed by T10 (43.63) at 60 DAS. The minimum number of nodules was found in control (T0) (27.67) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and found at par with single phytohormones priming i.e. T1 and T2. The percentage of number of nodules was increased in T9 by 45% at 30 DAS and 37.6% at 60 respectively as compared to the treatment T0. It was also observed that the percentage of nodules was lowest in control (T2) i.e. 25.3% and 22.3% at 30 and 60 DAS respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. In *Summer* 2023, it was recorded that the maximum number of nodules was found in T9 (38.53) followed by T10 (36.67) at 60 DAS. The minimum number of nodules was found in control (T0) (20.97) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and found at par with single phytohormones priming i.e. T1 and T2. The percentage of number of nodules was significantly increased in treatment T9 (i.e. combined micronutrient (Zn+B) foliar application in gibberellin primed seed plants) 57% at 30-DAS and 45.6% at 60-DAS when compared to treatment (T0) i.e control. It was also observed that the percentage of nodules was lowest in treatment (T1) i.e. 58.9% and 52.6% at 30 and 60 DAS respectively when compared with treatment (T6). Overall, the *Summer* seasons of 2022 and 2023 revealed that treatments T9 and T10 consistently resulted in the highest number of nodules, with T9 showing the greatest percentage increases in both years. The control group (T0) consistently had the lowest number of nodules, while treatments such as T6 and T7 demonstrated moderate improvements in the number of nodules compared to their respective controls.

Table 4.1.8.1 Effect of various treatments on number of nodules plant^{-1} of mung bean at 30 and 60 DAS during *Summer* season 2022 and 2023

	Number of nodules *Summer* 2022 and *Summer* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	$16.67^{g}\pm 1.53$	$11.33^{e}\pm 0.58$	$27.67^{f}\pm 2.31$	$20.97^{g}\pm 2.21$
T1	$19.33^{fg}\pm 1.53$	$13.33^{de}\pm 2.08$	$30.67^{ef}\pm 2.52$	$25.57^{efg}\pm 3.51$
T2	$19.67^{fg}\pm 2.52$	$12.67^{de}\pm 2.08$	$29.00^{ef}\pm 2.81$	$23.70^{fg}\pm 2.81$
T3	$22.67^{def}\pm 2.52$	$17.33^{bc}\pm 2.52$	$33.43^{cde}\pm 3.27$	$28.13^{cdef}\pm 3.27$
T4	$21.33^{ef}\pm 1.53$	$16.33^{cd}\pm 1.53$	$32.33^{def}\pm 3.20$	$27.03^{def}\pm 3.20$
T5	$26.00^{bcd}\pm 2.00$	$20.67^{b}\pm 2.08$	$39.67^{ab}\pm 2.52$	$33.90^{bc}\pm 3.82$
T6	$25.67^{cd}\pm 1.53$	$18.67^{bc}\pm 2.08$	$38.33^{bc}\pm 2.52$	$32.07^{bcd}\pm 3.57$
T7	$26.33^{bc}\pm 1.53$	$19.67^{bc}\pm 1.53$	$37.77^{bcd}\pm 3.57$	$32.13^{bcd}\pm 2.74$
T8	$24.67^{cde}\pm 2.52$	$18.00^{bc}\pm 1.73$	$36.63^{bcd}\pm 3.68$	$30.93^{bcde}\pm 3.68$
T9	$30.33^{a}\pm 1.53$	$26.33^{a}\pm 2.52$	$44.33^{a}\pm 3.51$	$38.53^{a}\pm 3.31$
T10	$29.33^{ab}\pm 1.53$	$24.33^{a}\pm 3.06$	$43.67^{a}\pm 2.52$	$36.67^{ab}\pm 2.75$
CD (at $p\leq 0.05$)	2.72	3.12	5.31	5.6
SEm (±)	0.91	1.05	1.79	1.88

In *Kharif* 2022 the percentage of number of nodules was significantly increased in treatment T10 (i.e. combined Zinc (Zn) and boron (B) foliar application in salicylic acid primed seed plants) 45.9% at 30 DAS and 41.5% at 60 respectively as compared to treatment (T0) control. It was also observed that the percentage of nodules was lowest in treatment (T4) i.e. 13.4% and 11.3% at 30, and 60 DAS respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023 it was recorded that the percentage of number of nodules was increased in T10 by 60.9% and 48% at 30 and 60 DAS respectively as compared to the control T0. It was also observed that percentage of number of nodules was lowest in control (T3) i.e. 19.9% at 30-DAS and 20% at 60-DAS respectively when compared with treatment (T5) i.e. foliar application of zinc in gibberellin primed seed plants. The *Kharif* seasons of 2022 and

2023 demonstrated that treatments T10 and T9 were most effective in increasing the number of nodules, with T10 showing the highest percentage increases in both years. The control group (T0) consistently had the lowest number of nodules, while other treatments such as T5 and T8 showed moderate improvements compared to their respective controls. Both the *Summer* and *Kharif* season crop of mung bean number of nodules was slightly greater in *Summer* season as we compare to *Kharif* season, number of nodules in the crop of *Summer* season was higher. As we compare both the 2022 and 2023 year crops, number of nodules of crop growing in 2022 year performs well as compare to crop grows in 2023 seasons. GA_3 priming can lead to longer roots and shoots, offering a stronger foundation for nutrient uptake and overall plant development. Longer roots increase the surface area available for nodule formation, which is vital for nitrogen fixation in legumes such as mung beans. A healthy and extensive root system improves the symbiotic relationship with Rhizobium bacteria, resulting in more efficient nodule formation and function **(Pandey et al., 2022; Islam *et al.,* 2023).** The combination of Salicylic acid priming and foliar zinc and boron application creates a synergistic effect that enhances overall plant health and nodulation. Nodules improve the nitrogen status of the plant, which in turn supports root growth and elongation (**Thapa *et al.,* 2023)**. A more extensive root system can support more nodules. Boron application has prevented boron deficiency incidence in the crop which has led to profuse root growth. Similar results were reported by **Rerkasem *et al.,* 2020; Pal *et al.,* 2023; Rafique *et al.,* 2021.**

Table 4.1.8.2 Effect of various treatments on number of nodules plant^{-1} of mung bean at 30 and 60 DAS during *Kharif* season 2022 and 2023

	Number of nodules *Kharif* 2022 and *Kharif* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	13.80^{f}± 1.01	8.33^{e}±1.53	22.33^{g}±2.08	17.33^{h}±1.53
T1	15.77^{ef}±1.00	10.00^{de}±1.00	26.67^{fg}±3.06	21.33^{fgh}±3.51
T2	14.90^{ef}±2.07	9.67^{de}±1.53	25.33^{fg}±1.53	19.33^{gh}±3.06
T3	19.63^{cd}±2.57	14.33^{bc}±2.08	30.00^{def}±2.00	24.73^{def}±3.27
T4	18.33^{de}±1.67	12.67^{cd}±1.53	28.67^{ef}±3.06	22.66^{efg}±2.52
T5	22.80^{bc}±2.21	17.9^{b}±2.21	35.00^{bc}±3.00	30.90^{bc}±3.82
T6	21.93^{bcd}±1.92	17.67^{b}±2.08	33.33^{cde}±2.52	30.33^{bc}±2.52
T7	22.67^{bc}±1.79	17.77^{b}±1.76	34.33^{bcd}±2.52	28.66^{cd}±2.08
T8	21.17^{cd}±2.24	16.33^{b}±1.53	32.33^{cde}±2.52	27.66^{cde}±3.51
T9	27.53^{a}±2.20	23.33^{a}±2.52	40.03^{a}±3.31	36.33^{a}±2.52
T10	25.50^{ab}±3.15	21.33^{a}±3.06	38.17^{ab}±2.75	33.33^{ab}±1.53
CD (at $p \leq 0.05$)	2.85	2.55	4.42	5
SEm (±)	0.95	0.85	1.49	1.68

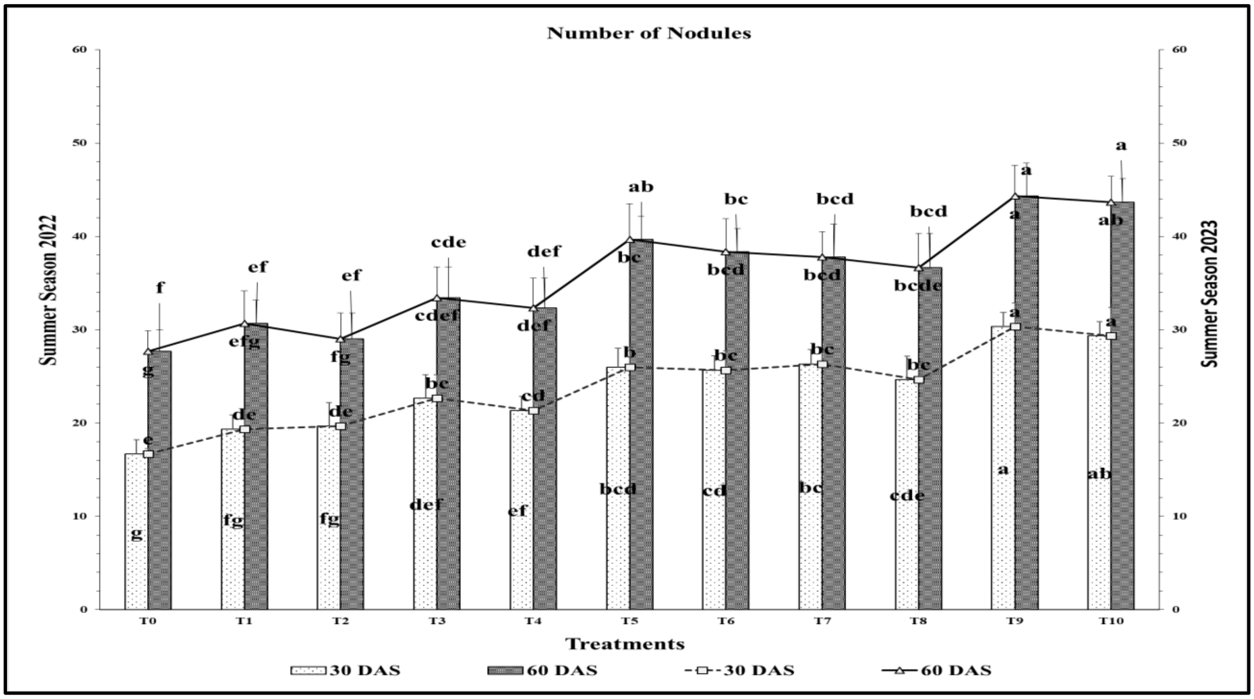


Figure 4.1.8.1a Effect of various treatments on number of nodules of mung bean at 30 and 60 DAS during *Summer* season 2022-23

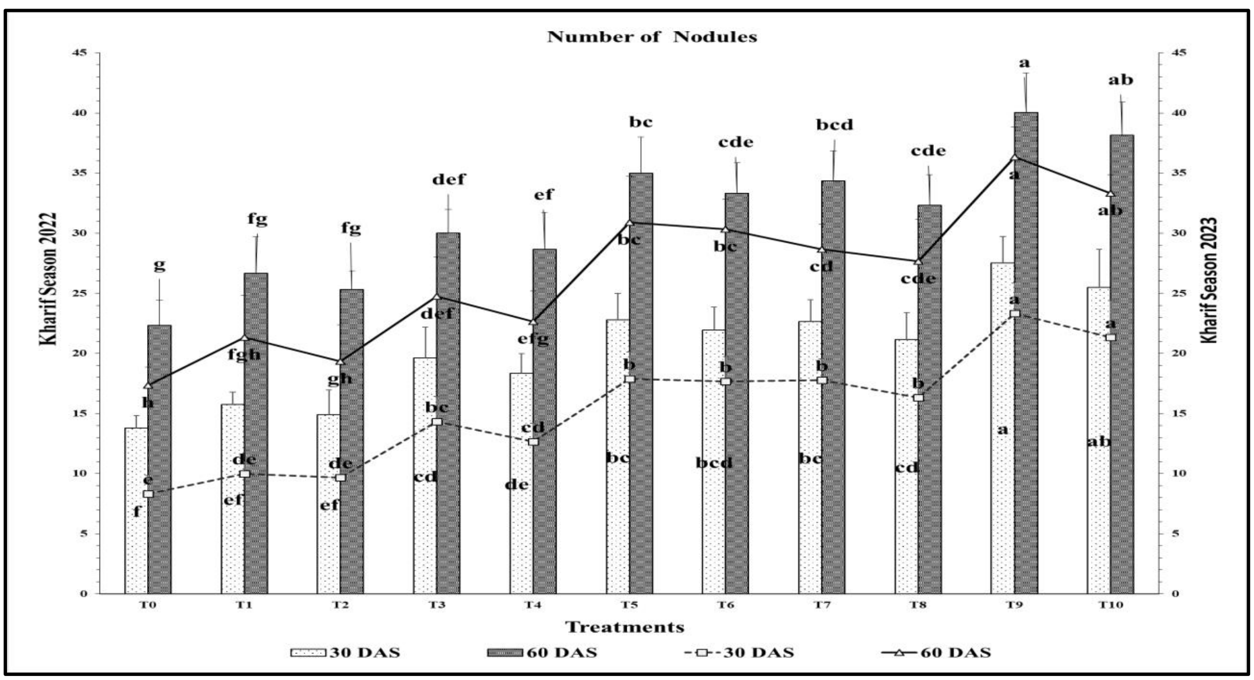


Figure 4.1.8.2a Effect of various treatments on number of nodules of mung bean at 30 and 60 DAS during *Kharif* season 2022-23

4.1.9 Leaf Area Index

The effect of seed priming with gibberellin, salicylic acid and foliar application of zinc and boron on leaf area was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of leaf area was recorded at 30-days and 60-DAS (Table 4.1.9.1, 4.1.9.2 and Figure 4.1.9.1a and Figure 4.1.9.2a). In 2022 and 2023, there was a significant difference in the percentage of leaf area by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that the maximum area of leaves was found in T9 (18.06 cm^2) followed by T10 (17.72 cm^2) at 60 DAS. The minimum leaf area was found in control (T0) (13.17 cm^2) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and found at par with single phytohormones priming i.e. T1 and T2. The percentage of leaf area index was increased in T9 by 25.8% at 30 DAS and 27.1% at 60 DAS when compared to the control T0. It was also observed that percentage of leaf area index was lowest in control (T2) i.e. 16.5% and 16.4% at 30 and 60 DAS respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. In *Summer* 2023 the percentage of leaf area index was significantly increased in treatment T9 (i.e. combined mcronutrient foliar application in gibberellin primed seed plants) 27.2% at 30-DAS and 30.3% at 60-DAS respectively as compared to control (T0). It was also observed that percentage of leaf area index was lowest in treatment (T1) i.e. 21.2% and 25.5% at 30 and 60 DAS respectively when compared with treatment (T6). Overall, the *Summer* seasons of 2022 and 2023 revealed that treatments T9 and T10 consistently resulted in the maximum leaf area, with T9 showing the greatest percentage increases in both years. The control group (T0) consistently had the lowest leaf area, while treatments such as T6 and T7 demonstrated moderate improvements in leaf area index compared to their respective controls.

Table 4.1.9.1 Effect of various treatments on leaf area index of mung bean at 30 and 60 DAS during *Summer* season 2022 and 2023

	Leaf Area Index *Summer* 2022 and *Summer* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	0.56^{f}±0.018	0.52^{h}±0.017	3.66^{e}±0.87	3.12^{f}±0.79
T1	0.61^{e}±0.025	0.56^{fgh}±0.022	3.82^{de}±0.41	3.31^{def}±0.41
T2	0.58^{e}±0.031	0.54^{gh}±0.028	3.74^{e}±0.68	3.25^{ef}±0.53
T3	0.63^{de}±0.0328	0.58^{ef}±0.021	4.21^{bcd}±0.23	3.70^{cde}±0.26
T4	0.63^{de}±0.018	0.57^{fg}±0.017	3.91^{cde}±1.08	3.39^{def}±1.19
T5	0.71^{ab}±0.025	0.66^{bc}±0.020	4.53^{b}±0.88	4.00^{bc}±0.84
T6	0.67^{cd}±0.021	0.63^{cd}±0.023	4.42^{b}±0.59	3.91^{bc}±0.59
T7	0.7^{bc}±0.037	0.62^{de}±0.016	4.47^{b}±0.59	3.93^{bc}±0.56
T8	0.66^{cd}±0.023	0.59^{def}±0.020	4.26^{bc}±1.13	3.75^{cd}±1.13
T9	0.76^{a}±0.027	0.71^{a}±0.021	5.02^{a}±1.05	4.47^{a}±1.43
T10	0.73^{ab}±0.031	0.68^{ab}±0.024	4.92^{a}±0.86	4.36^{ab}±1.14
CD (at p≤ 0.05)	0.043	0.027	0.4	0.43
SEm (±)	0.014	0.009	0.14	0.15

In *Kharif* 2022 the percentage of leaf area index was significantly increased in treatment T10 (i.e. combined foliar form application of Zinc (Zn) and boron (B) in salicylic acid primed seed plants) 25.2% at 30 DAS and 27.8% at 60 respectively as compared to control (T0). It was also observed that percentage of leaf area index was lowest in treatment (T4) i.e. 5.5% and 9.4% at 30, and 60-DAS respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023 it was recorded that the maximum leaf area was found in T9 (8.76 cm^2) followed by T10 (8.07 cm^2) at 60 DAS. The minimum leaf area was found in control (T0) (5.36 cm^2) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and found at par with single phytohormones priming i.e. T1 and T2. The percentage of leaf area index was increased in T10 by 60.9% at 30-DAS and 33.6%

at 60-DAS respectively as compared to the treatment T0. It was also observed that percentage of leaf area index was lowest in control (T3) i.e. 19.9% and 13.8% at 30 and 60 DAS respectively when compared with treatment (T5) i.e. foliar application of zinc in gibberellin primed seed plants. The *Kharif* seasons of 2022 and 2023 demonstrated that treatments T10 and T9 were most effective in increasing the leaf area index, with T10 showing the highest percentage increases in 2022 and T9 showing the maximum leaf area in 2023. The control group (T0) consistently had the lowest leaf area, while other treatments such as T5 and T8 showed moderate improvements compared to their respective controls. Both the *Summer* and *Kharif* season crop of mung bean leaf area index was slightly greater in *Summer* season as we compare to *Kharif* season, leaf area index in the crop of *Summer* season was higher. As we compare both the 2022 and 2023 year crops, leaf area index of crop growing in 2022 year performs well as compare to crop grows in 2023 seasons. Priming seeds with GA and foliar application of Zn and B can significantly impact leaf area in mung beans. It stimulates the expansion of leaves by increasing the plasticity of cell walls, allowing cells to grow more extensively **(Dass *et al.,* 2022)**. Boron deficiency can lead to reduced leaf area due to impaired cell division and expansion. A larger leaf area often supports greater photosynthetic activity, providing more energy for plant growth, and leading to increased plant height also **Haider *et al.,* 2020; Ajmal *et al.,* 2023; Bagale *et al.,* 2021.** Foliar application of zinc is involved in the synthesis of auxin, a hormone that regulates plant growth and leaf size. There is typically a positive correlation between leaf area and leaf number. More leaves usually contribute to a greater total leaf area **(Karmakar *et al.,* 2021; Selim *et al.,* 2023).** A larger leaf area can support more branches by providing more surface area for photosynthesis, which enhances energy availability. Increased leaf area contributes to improved growth characteristics, such as greater plant height and more branches, while a sufficient supply of nutrients and proper hormonal balance ensure optimal leaf development and overall plant performance **Aslam *et al.,* 2021; Haider *et al.,* 2021.**

Table 4.1.9.2 Effect of various treatments on leaf area index of mung bean at 30 and 60 DAS during *Kharif* season 2022 and 2023

	Leaf Area Index *Kharif* 2022 and *Kharif* 2023			
	30 DAS		**60 DAS**	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	0.56^{f}±0.018	3.66^{e}±0.87	0.52^{h}±0.017	3.12^{f}±0.79
T1	0.61^{e}±0.025	3.82^{de}±0.41	0.56^{fgh}±0.022	3.31^{def}±0.41
T2	0.58^{e}±0.031	3.74^{e}±0.68	0.54^{gh}±0.028	3.25^{ef}±0.53
T3	0.63^{de}±0.0328	4.21^{bcd}±0.23	0.58^{ef}±0.021	3.70^{cde}±0.26
T4	0.63^{de}±0.018	3.91^{cde}±1.08	0.57^{fg}±0.017	3.39^{def}±1.19
T5	0.71^{ab}±0.025	4.53^{b}±0.88	0.66^{bc}±0.020	4.00^{bc}±0.84
T6	0.67^{cd}±0.021	4.42^{b}±0.59	0.63^{cd}±0.023	3.91^{bc}±0.59
T7	0.7^{bc}±0.037	4.47^{b}±0.59	0.62^{de}±0.016	3.93^{bc}±0.56
T8	0.66^{cd}±0.023	4.26^{bc}±1.13	0.59^{def}±0.020	3.75^{cd}±1.13
T9	0.76^{a}±0.027	5.02^{a}±1.05	0.71^{a}±0.021	4.47^{a}±1.43
T10	0.73^{ab}±0.031	4.92^{a}±0.86	0.68^{ab}±0.024	4.36^{ab}±1.14
CD (at p≤ 0.05)	0.043	0.4	0.027	0.43
SEm (±)	0.014	0.14	0.009	0.15

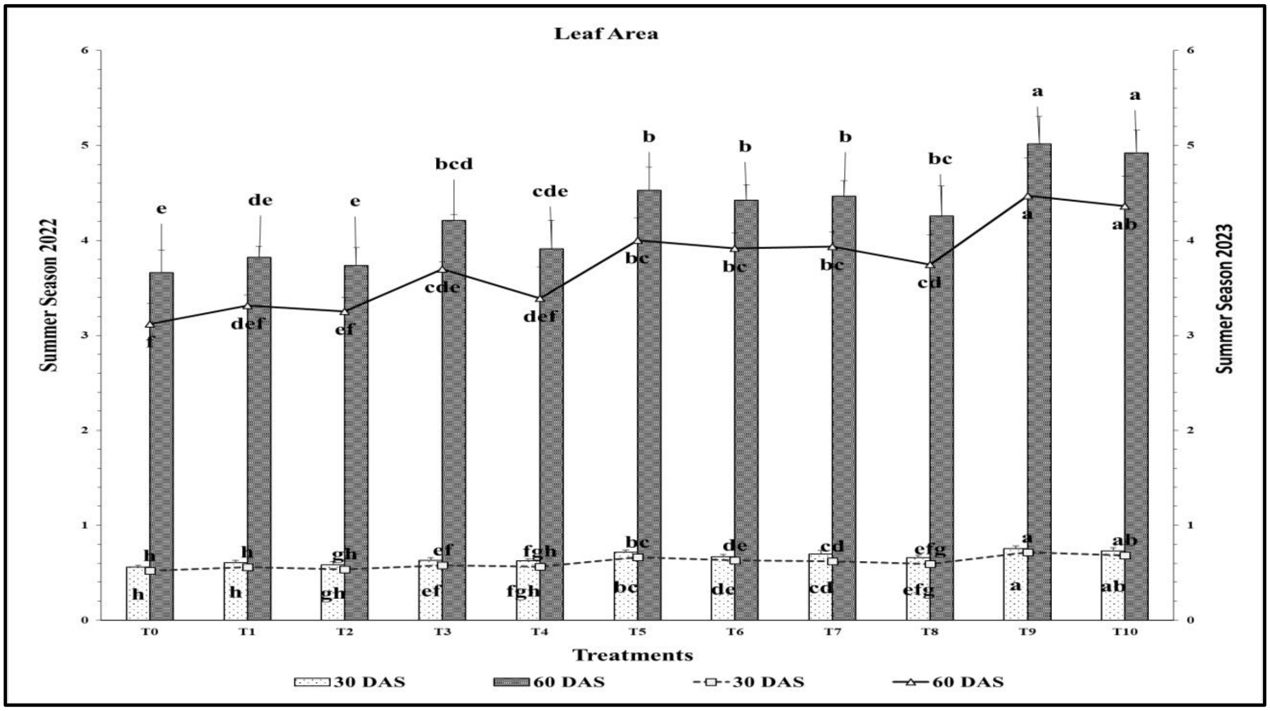


Figure 4.1.9.1a Effect of various treatments on leaf area index of mung bean at 30 and 60 DAS during *Summer* season 2022-23

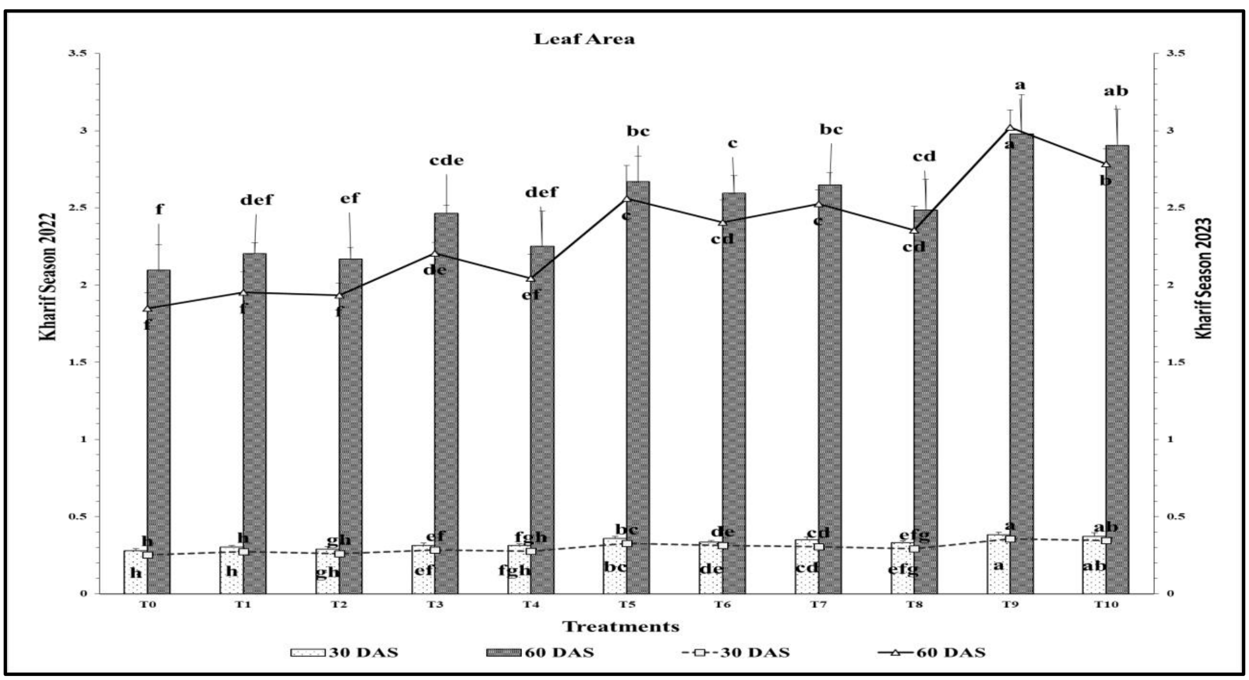


Figure 4.1.9.2a Effect of various treatments on leaf area index of mung bean at 30 and 60 DAS during *Kharif* season 2022-23

4.1.10 Days to 50% flowering

The effect of priming seeds with gibberellin, salicylic acid and micronutrients foliar application of zinc and boron on 50% flowering days was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of 50% flowering days was recorded at 30 and 60 DAS (Table 4.1.10.1, 4.1.10.2 and Figure 4.1.10.1a, 4.1.10.2a). In 2022 and 2023, there was a significant difference in the percentage (%) of days to 50% flowering by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that the maximum days to 50% flowering was found in T0 (41.33) followed by T2 (40.67) at 60 DAS. The minimum days to 50% flowering was found in treatment T9 (36.67). The percentage of 50% flowering days was higher in control T0 by 11.3% respectively as compared to the T9. It was also observed that percentage of days to 50% flowering was lowest in T7 (i.e. foliar application of zinc in salicylic acid primed seed plants) 7.4% when compared with treatment (T2). In *Summer* 2023, it was recorded the maximum days to 50% flowering was found in T0 (42) followed by T2 (41.67) at 60 DAS. The minimum days to 50% flowering was found in T9 (37.67). The percentage of days to 50% flowering was significantly higher in control T0 by 10.3% respectively as compared to the T9 (i.e. combined foliar application of zinc and boron in gibberellin primed seed plants). It was also observed that percentage of days to 50% flowering was lowest in treatment (T6) (i.e. foliar application of boron in Gibberellin primed seed plants) by 3.3% respectively when compared with treatment (T1) (i.e. individual application of gibberellin primed seeds). Overall, both *Summer* seasons demonstrated that the control (T0) consistently resulted in the mamimum days to 50% flowering, indicating a delay in flowering. In contrast, treatments T9 and T7 effectively reduced the number of days to 50% flowering, promoting earlier flowering in both years.

Table 4.1.10.1 Effect of various treatments on days to 50% flowering of mung bean during *Summer* season 2022 and 2023

Treatments	Days to 50% flowering *Summer* 2022	Days to 50% flowering *Summer* 2023
T0	$41.33^{a}\pm1.51$	$42.00^{a}\pm1.00$
T1	$40.33^{ab}\pm0.57$	$41.33^{ab}\pm0.58$
T2	$40.67^{ab}\pm1.15$	$41.67^{ab}\pm1.15$
T3	$39.33^{bcd}\pm0.57$	$40.33^{bcd}\pm0.58$
T4	$39.67^{bc}\pm1.15$	$40.67^{abc}\pm1.15$
T5	$37.33^{e}\pm0.57$	$39.00^{def}\pm0.00$
T6	$38.00^{de}\pm1.00$	$39.33^{cde}\pm0.58$
T7	$37.67^{e}\pm0.57$	$39.33^{cde}\pm1.15$
T8	$38.33^{cde}\pm1.15$	$39.67^{cde}\pm0.58$
T9	$36.67^{e}\pm0.57$	$37.67^{f}\pm0.58$
T10	$37.00^{e}\pm1.00$	$38.67^{ef}\pm0.58$
CD	1.49	1.39
SE(m)	0.50	0.46

In *Kharif* 2022 the percentage of days to 50% flowering was significantly increased in treatment T0 (i.e. control) 9.4% respectively as compared to (T10) (i.e. Zinc (Zn) and boron (B) foliar application in salicylic acid primed seed plants). It was also observed that percentage of days to 50% flowering was lowest in treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants) 1.6% respectively when compared with treatment (T4). In *Kharif* 2023 the percentage of days to 50% flowering was significantly increased in treatment T0 (i.e. control) 7.7% respectively as compared to (T10) (i.e. Zinc (Zn) and boron (B) foliar application in salicylic acid primed seed plants). Similarly, it was found that the treatment T1 (i.e. individual application of gibberellin primed seed plants) having the higher percentage of days to 50% flowering by 4.8% respectively when compared with treatment T5. It was also observed that percentage of days to 50% flowering was lowest in treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants) by 2.4% respectively when compared with treatment (T4). The *Kharif* seasons of 2022 and 2023 confirmed that control conditions (T0) consistently delayed the flowering process, as indicated by the highest number of days to 50% flowering. Treatments T10, T8, and T5 were more effective in reducing the number of days to 50% flowering, thereby promoting earlier flowering. Both the *Summer* and *Kharif* season crop of mung bean days to 50% flowering was slightly lesser in *Summer* season as we compare to *Kharif* season, days to 50% flowering in the crop of *Kharif* season was higher. GA promotes flowering in many plants by triggering the shift from the vegetative to the reproductive growth phase. It also balances various plant hormones, such as abscisic acid, which can delay flowering. By lowering abscisic acid levels, GA accelerates the flowering process. Adequate zinc levels ensure the proper functioning of auxins and other growth hormones, which can affect the timing of flowering (**Raina *et al.*, 2020; Kayata *et al.*, 2024)**. Early flowering plants with a well-developed leaf area can maintain higher photosynthetic rates during the reproductive phase, supporting better yield (**Umair *et al.*, 2020).** Early flowering might lead to better resource allocation towards reproductive structures (flowers and pods), enhancing yield. The combined use of GA, zinc, and boron ensures that the plant's vegetative growth is robust and supports a healthy transition to the reproductive phase, optimizing both yields (**Pal *et al.*, 202; Ajmal *et al.*, 20231; Dhaliwal *et al.*, 2021).**

Table 4.1.10.2 Effect of various treatments on days to 50% flowering of mung bean during *Kharif* season 2022 and 2023

Treatments	Days to 50% flowering *Kharif* 2022	Days to 50% flowering *Kharif* 2023
T0	42.67^{a}±0.58	43.00^{a}±0.00
T1	41.33^{abc}±0.58	42.00^{abc}±1.00
T2	41.67^{ab}±1.15	42.67^{ab}±1.15
T3	40.00^{cde}±1.00	41.33^{bcde}±0.58
T4	40.33^{bcd}±0.58	41.67^{abcd}±0.58
T5	39.00^{def}±0.00	40.00^{ef}±0.00
T6	39.67^{de}±0.58	40.33^{def}±0.58
T7	39.00^{def}±1.00	40.00^{ef}±1.00
T8	39.67^{de}±0.58	40.67^{cdef}±0.58
T9	38.00^{f}±1.00	39.33^{f}±1.15
T10	38.67^{ef}±0.58	39.67^{f}±0.58
CD	1.36	1.35
SE(m)	0.46	0.45

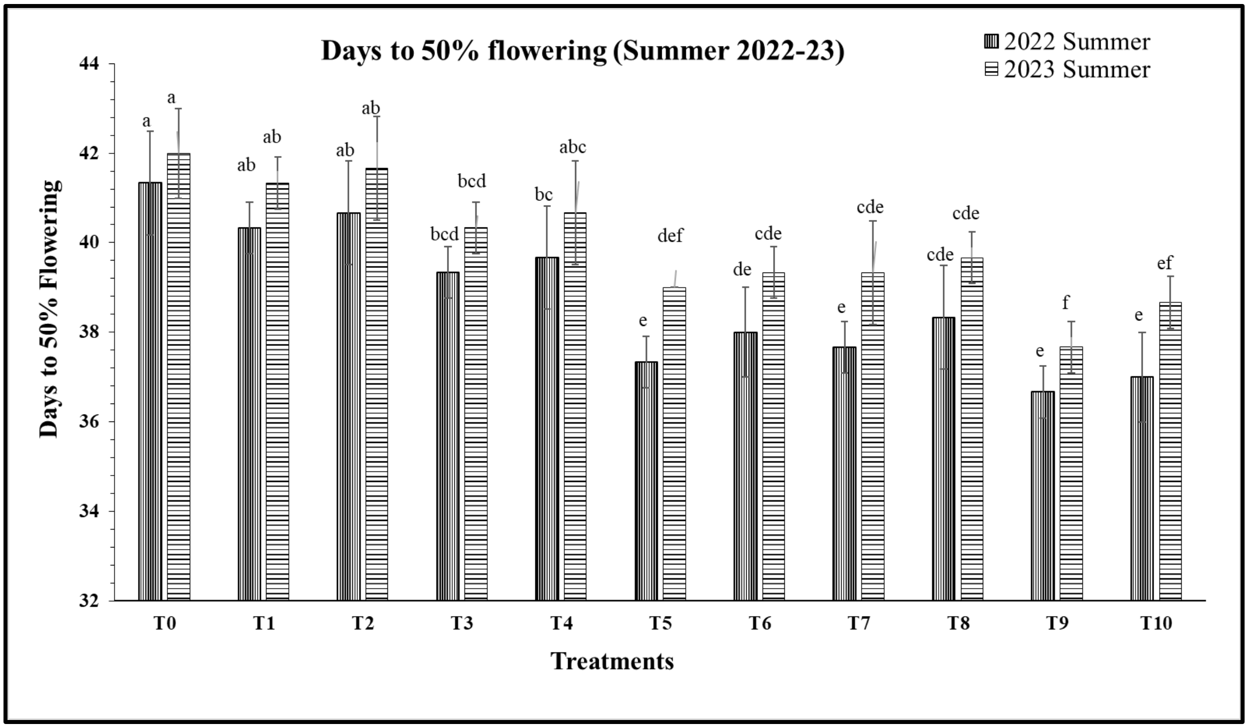


Figure 4.1.10.1a Effect of various treatments on days to 50% flowering of mung bean during *Summer* season 2022 and 2023

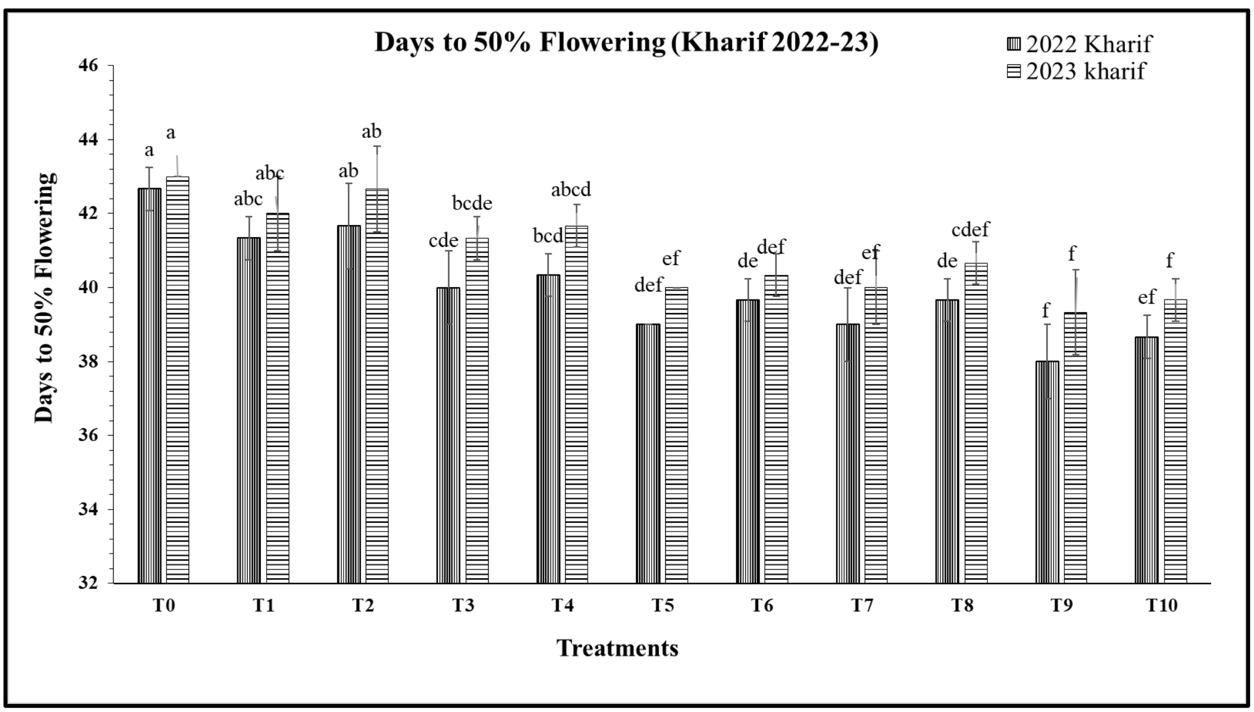


Figure 4.1.10.2a Effect of various treatments on days to 50% flowering of mung bean during *Kharif* season 2022 and 2023

4.1.11 Crop Growth Rate (g/m^2/day)

The effect of priming seeds with gibberellin, salicylic acid and micronutrients foliar application on crop growth rate was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of crop growth rate was observed at 30-days, 60-DAS intervals or at harvest (Table 4.1.11.1, 4.1.11.2 and Figure 4.1.11.1a and Figure 4.1.11.2a). In *Summer* 2022 it was recorded that the maximum crop growth rate was found in T9 (0.31) followed by (T10) (0.29) at 60 DAS. The minimum crop growth rate was found in control T0 (0.16). The percentage of crop growth rate was increased in T9 by 48.4% and 2.7% at 60-DAS intervals or at harvest when compared to the treatment T0 i.e. (control). It was also observed that percentage of crop growth rate was lowest in control (T2) i.e. 36% at 60 DAS and 7.9% at harvest when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. Similarly, it was found that the treatment T6 (i.e. foliar application of boron in Gibberellin primed seed plants) enhanced the percentage of crop growth rate by 30.4% at 60 DAS and 17.1% at harvest when compared with treatment T4 i.e. individual foliar application of boron. In *Summer* 2023, it was recorded that the maximum crop growth rate was found in T9 (0.26) followed by (T10) (0.25) at 60 DAS. The minimum crop growth rate was found in control T0 (0.19). The percentage of crop growth rate was significantly increased in treatment T9 (i.e. combined foliar application of Zinc and boron in gibberellin primed seed plants) 26.9% at 60-DAS and 34.1% at harvest when compared to treatment (T0) control. It was also observed that percentage of crop growth rate was lowest in treatment (T1) i.e. 29.6% at 60-DAS and at harvest when compared with treatment (T6). Overall, both *Summer* seasons (2022 and 2023) indicated that the combined foliar application of zinc and boron in gibberellin-primed seed plants (T9) consistently resulted in the highest crop growth rate. In contrast, the control treatment (T0) showed the lowest crop growth rate, confirming the positive impact of micronutrient treatments on crop growth performance.

Table 4.1.11.1 Effect of various treatments on crop growth rate (g/m^2/day) of mung bean at 60 DAS and at harvest during *Summer* season 2022 and 2023

	Crop Growth Rate (g/m^2/day) *Summer* 2022 and *Summer* 2023			
	30-60 DAS		60 -At harvest	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	0.16^{f}±0.015	0.19^{i}±0.013	0.36^{abc}±0.014	0.27^{bc}±0.087
T1	0.16^{ef}±0.002	0.2^{hi}±0.010	0.35^{abc}±0.019	0.25^{c}±0.014
T2	0.16^{f}±0.018	0.19^{i}±0.003	0.35^{cd}±0.006	0.25^{c}±0.066
T3	0.19^{d}±0.009	0.21^{gh}±0.009	0.33^{d}±0.013	0.35^{abc}±0.083
T4	0.19^{de}±0.007	0.2^{hi}±0.015	0.34^{cd}±0.002	0.32^{abc}±0.058
T5	0.26^{b}±0.005	0.24^{abc}±0.011	0.37^{abc}±0.024	0.39^{a}±0.082
T6	0.23^{c}±0.012	0.23^{bcd}±0.015	0.41^{a}±0.014	0.35^{abc}±0.059
T7	0.25^{b}±0.012	0.23^{de}±0.009	0.38^{ab}±0.036	0.43^{a}±0.082
T8	0.22^{c}±0.009	0.22^{efg}±0.003	0.36^{abc}±0.013	0.37^{ab}±0.054
T9	0.31^{a}±0.013	0.26^{a}±0.018	0.37^{bc}±0.027	0.41^{a}±0.039
T10	0.29^{a}±0.014	0.25^{ab}±0.009	0.33^{d}±0.017	0.41^{a}±0.056
CD (at p≤ 0.05)	0.021	0.051	0.031	0.058
SEm (±)	0.007	0.017	0.01	0.02

In *Kharif* 2022 the percentage of crop growth rate was significantly increased in treatment T10 (i.e. Zinc (Zn) and boron (B) foliar application in salicylic acid primed seed plants) 30.1% at 60-DAS and 38.1% at harvest when we compared it with treatment (T0) control. It was also observed that percentage of crop growth rate was lowest in treatment (T4) i.e. 8.1% at 60 DAS and 20% at harvest when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023 it was recorded that the percentage of crop growth rate was increased in T10 by 37.5% 60 DAS respectively as compared to the control T0. It was also observed that percentage of crop growth rate was lowest in control (T0) i.e. 17.6% at 60-DAS and 6.7% at harvest respectively when compared with treatment (T5) i.e. foliar application of zinc in gibberellin primed seed plants. Similarly, it was found that the treatment T8 (i.e. foliar application of boron in salicylic acid primed seed plants) enhanced the percentage of crop growth rate by 19.7% at 60 DAS and 20% at harvest respectively when compared with treatment T2 i.e. individual priming of seeds with salicylic acid. Both *Kharif* seasons (2022 and 2023) demonstrated that the zinc (Zn) and boron (B) foliar application in primed seed plants (T10) led to a significant increase in crop growth rate. In contrast, the control treatment (T0) consistently showed the lowest crop growth rate, underscoring the effectiveness of micronutrient applications in enhancing crop growth during the *Kharif* season. Both the *Summer* and *Kharif* season crop of mung bean crop growth rate was slightly greater in *Summer* season as we compare to *Kharif* season, crop growth rate in the crop of *Summer* season was higher. GA priming, along with foliar applications of zinc and boron, can greatly improve the crop growth rate of mung beans. This combination positively impacts various morphological and yield traits, resulting in stronger plants with higher yields. GA priming produces more vigorous seedlings that establish rapidly and compete more effectively against weeds. The results are supported by **Gómez *et al.,* 2018; Aslam *et al.,* 2023; Islam *et al.,* 2021.** Foliar applications of Zn and B ensure that plants have sufficient micronutrients, preventing deficiencies that could limit growth and yield. Faster growth rates result in greater biomass accumulation, directly contributing to yield **(WIN 2019)**. Boron plays a crucial role in reproductive development. Improved flowering and fruit set increase the potential for higher yields. **Photosynthetic efficiency** is enhanced by GA, Zn, and B through better chlorophyll synthesis and function. These results are similar to **Shireen *et al.,* 2018; Islam et al., 2023; Koul *et al.,* 2022.**

Table 4.1.11.2 Effect of various treatments on crop growth rate g/m^2/day of mung bean at 60 DAS and at harvest during *Kharif* season 2022 and 2023

	Crop growth rate (g/m^2/day) *Kharif* 2022 and *Kharif* 2023			
	30-60 DAS		60 -At harvest	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	0.51^{g}±0.024	0.45^{h}±0.036	0.13^{c}±0.042	0.15^{a}±0.031
T1	0.56^{fg}±0.025	0.51^{fgh}±0.017	0.18^{bc}±0.030	0.12^{ab}±0.012
T2	0.53^{fg}±0.024	0.49^{gh}±0.011	0.17^{bc}±0.053	0.12^{ab}±0.032
T3	0.58^{ef}±0.019	0.56^{ef}±0.032	0.21^{ab}±0.010	0.14^{a}±0.013
T4	0.57^{f}±0.035	0.54^{fg}±0.47	0.2^{ab}±0.012	0.12^{ab}±0.007
T5	0.7^{bc}±0.032	0.68^{bc}±0.044	0.19^{abc}±0.050	0.15^{a}±0.004
T6	0.64^{d}±0.031	0.64^{cd}±0.028	0.21^{ab}±0.012	0.15^{a}±0.025
T7	0.67^{cd}±0.026	0.66^{bcd}±0.027	0.2^{ab}±0.020	0.15^{a}±0.19
T8	0.62^{de}±0.036	0.61^{de}±0.028	0.25^{a}±0.038	0.15^{a}±0.025
T9	0.77^{a}±0.018	0.80^{a}±0.015	0.21^{ab}±0.007	0.09^{b}±0.017
T10	0.73^{ab}±0.024	0.72^{b}±0.021	0.21^{ab}±0.037	0.14^{a}±0.029
CD (at p≤ 0.05)	0.051	0.048	0.058	NS
SEm (±)	0.017	0.016	0.02	0.014

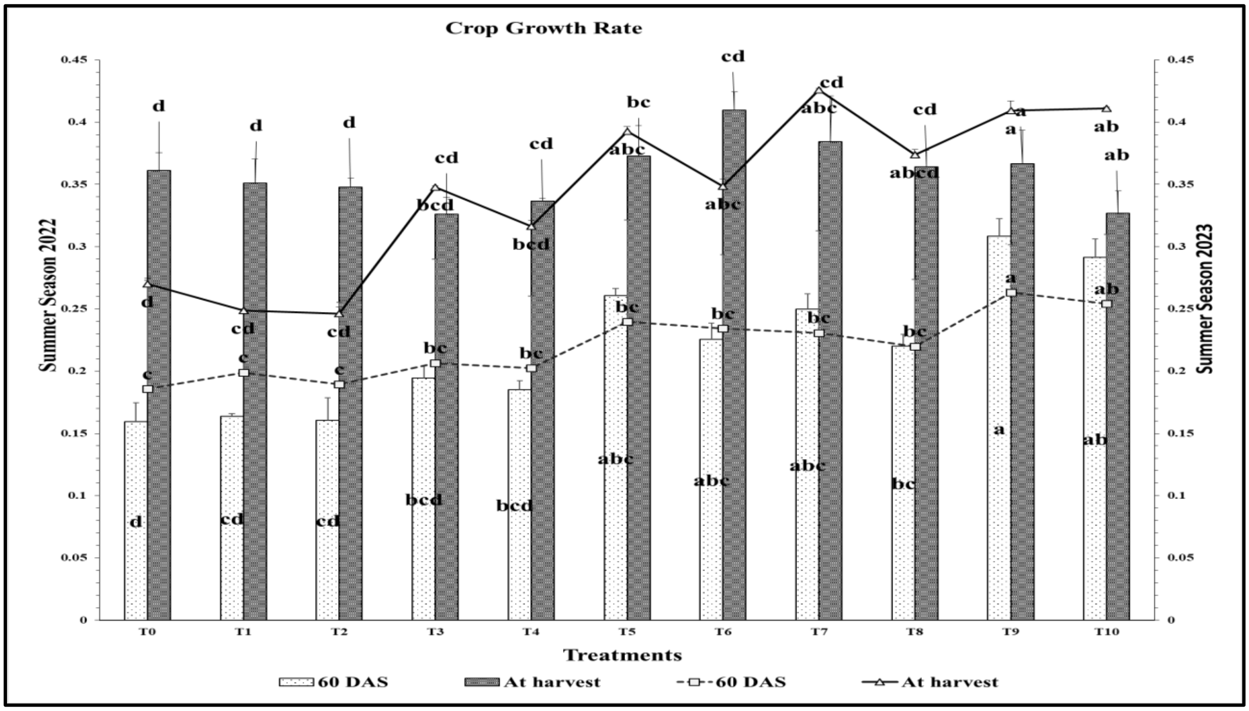


Figure 4.1.11.1a Effect of various treatments on crop growth rate g/m^2/day of mung bean at 60 DAS and at harvest during *Summer* season 2022-23

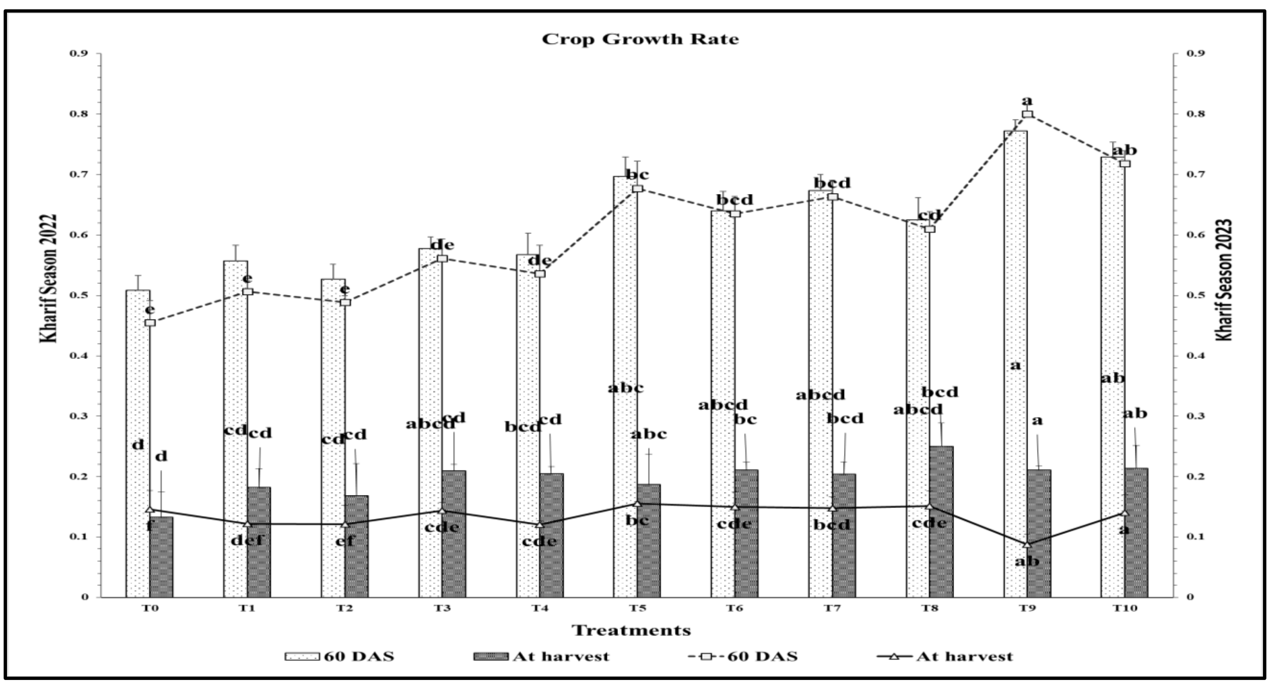


Figure 4.1.11.2a Effect of various treatments on crop growth rate g/m^2/day of mung bean at 60 DAS and at harvest during *Kharif* season 2022-23

4.1.12 Relative Growth Rate (RGR) (g/g/day)

The effect of priming seeds with gibberellin, salicylic acid and micronutrients foliar application of zinc and boron on relative growth rate was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of relative growth rate was observed at 30, 60-DAS intervals and at harvest sown in the (Table 4.1.12.1, 4.1.12.2 and Figure 4.1.12.1a and Figure 4.1.12.2a). In 2022 and 2023, there was a non-significant effect on the relative growth rate by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that the relative growth rate at 60 DAS was found non-significant. However, the maximum and minimum RGR 0.054 g/g/day and 0.047 g/g/day were recorded by treatment T9 and T2 respectively. The RGR at harvest was found non-significant. However, the maximum and minimum relative growth rate 0.0043 g/g/day and 0.0002 g/g/day were recorded by treatment T7 and T6 respectively. In *Summer* 2023 the RGR at 60 DAS was found non-significant. However, the maximum and minimum RGR 0.006 g/g/day and 0.0005 g/g/day were recorded by treatment T0 and T10 respectively. The RGR at harvest was found non-significant. However, the maximum and minimum RGR 0.044 and 0.031 g/g/day were recorded by treatment T8 and T1 respectively. When comparing the two *Summer*s, *Summer* 2022 had a generally higher RGR range both at 60-DAS and at harvest compared to *Summer* 2023. *Summer* 2022 displayed a wider range of RGR values, indicating potentially more variability in growth responses to the treatments compared to the more clustered RGR values in *Summer* 2023.

Table 4.1.12.1 Effect of various treatments on relative growth rate (g/g/day) of mung bean at 60 DAS and at harvest during *Summer* season 2022 and 2023

	Relative Growth Rate (g/g/day) *Summer* 2022 and *Summer* 2023			
	30-60 DAS		**60 -At harvest**	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	0.051[a]±0.007	0.063[a]±0.006	0.049[a]±0.001	0.036[a]±0.011
T1	0.045[a]±0.005	0.061[a]±0.002	0.045[a]±0.003	0.031[a]±0.001
T2	0.047[a]±0.007	0.061[a]±0.003	0.046[a]±0.002	0.032[a]±0.008
T3	0.048[a]±0.002	0.061[a]±0.000	0.037[a]±0.001	0.041[a]±0.009
T4	0.048[a]±0.000	0.061[a]±.0005	0.04[a]±0.001	0.038[a]±0.007
T5	0.052[a]±0.002	0.06[a]±0.002	0.033[a]±0.001	0.04[a]±0.008
T6	0.05[a]±0.003	0.062[a]±0.005	0.04[a]±0.000	0.037[a]±0.006
T7	0.051[a]±0.002	0.06[a]±0.000	0.036[a]±0.004	0.044[a]±0.008
T8	0.05[a]±0.004	0.061[a]±0.002	0.037[a]±0.001	0.041[a]±0.006
T9	0.054[a]±0.003	0.06[a]±0.005	0.029[a]±0.002	0.038[a]±0.004
T10	0.053[a]±0.002	0.06[a]±0.000	0.027[a]±0.002	0.039[a]±0.005
CD (at p≤ 0.05)	NS	NS	NS	NS
SEm (±)	0.003	0.002	0.001	0.004

In *Kharif* 2022 the RGR at 60 DAS was found non-significant. However, the maximum and minimum RGR 0.060 and 0.056 g/g/day were recorded by treatment T7 and T2, T3 respectively. The RGR at harvest was found non-significant. However, the maximum and minimum RGR 0.026 and 0.018 g/g/day were recorded by treatment T8 and T0, T5 respectively. In *Kharif* 2023 the maximum and minimum RGR 0.0064 and 0.0018 g/g/day were recorded by treatment T0 and T10 respectively. The RGR at harvest was found non-significant. However, the maximum and minimum RGR 0.0048 and 0.0009 g/g/day were recorded by treatment T0 and T5 respectively. When comparing *Kharif* 2022 to *Kharif* 2023, both periods showed non-significant results with generally lower RGR values compared to the *Summer* seasons. *Kharif* 2023 had a narrower range of RGR values compared to *Kharif* 2022, reflecting a more constrained growth response to treatments in 2023. RGR is a measure of the growth of a plant relative to its size over a given period. In mung bean (*Vigna radiata*), RGR can significantly influence crop yield and various morphological parameters. Higher RGR during early growth stages can lead to faster canopy development, better light interception, and enhanced photosynthesis, which contribute to higher biomass accumulation. As the plant matures, the relative growth rate (RGR) usually decreases because of higher respiration costs and the diversion of resources to reproductive structures. RGR is closely linked to leaf area expansion; plants with a higher RGR often have larger leaf areas, boosting their photosynthetic capacity. A plant's ability to adapt its growth to varying environmental conditions can result in non-significant differences in RGR when averaged across different conditions. In some cases, plants may allocate resources differently, prioritizing reproductive growth over vegetative growth or vice versa, leading to non-significant RGR changes despite differences in yield or morphology. Similar results were obtained by **Singh *et al.,* 2020; Chamara *et al.,* 2020; Behera *et al.,* 2021; Masih *et al.,* 2020**.

Table 4.1.12.2 Effect of various treatments on relative growth rate (g/g/day) of mung bean at 60 DAS and at harvest during *Kharif* season 2022 and 2023

	Relative Growth Rate (g/g/day) *Kharif* 2022 and *Kharif* 2023			
	30-60 DAS		**60 -At harvest**	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	0.058[a]±0.002	0.067[a]±0.006	0.018[a]±0.005	0.022[a]±0.004
T1	0.058[a]±0.002	0.066[a]±0.004	0.022[a]±0.003	0.017[a]±0.001
T2	0.056[a]±0.002	0.067[a]±0.004	0.021[a]±0.006	0.018[a]±0.004
T3	0.056[a]±0.001	0.064[a]±0.004	0.023[a]±0.001	0.018[a]±0.002
T4	0.058[a]±0.002	0.064[a]±0.006	0.024[a]±0.002	0.016[a]±0.001
T5	0.059[a]±0.003	0.063[a]±0.004	0.018[a]±0.005	0.016[a]±0.000
T6	0.059[a]±0.003	0.064[a]±0.004	0.022[a]±0.00	0.017[a]±0.002
T7	0.06[a]±0.003	0.064[a]±0.003	0.02[a]±0.001	0.016[a]±0.001
T8	0.058[a]±0.004	0.064[a]±0.003	0.026[a]±0.004	0.017[a]±0.003
T9	0.058[a]±0.002	0.061[a]±0.002	0.019[a]±0.000	0.008[a]±0.001
T10	0.057[a]±0.002	0.061[a]±0.001	0.02[a]±0.003	0.014[a]±0.002
CD (at p≤ 0.05)	NS	NS	NS	NS
SEm (±)	0.002	0.002	0.002	0.002

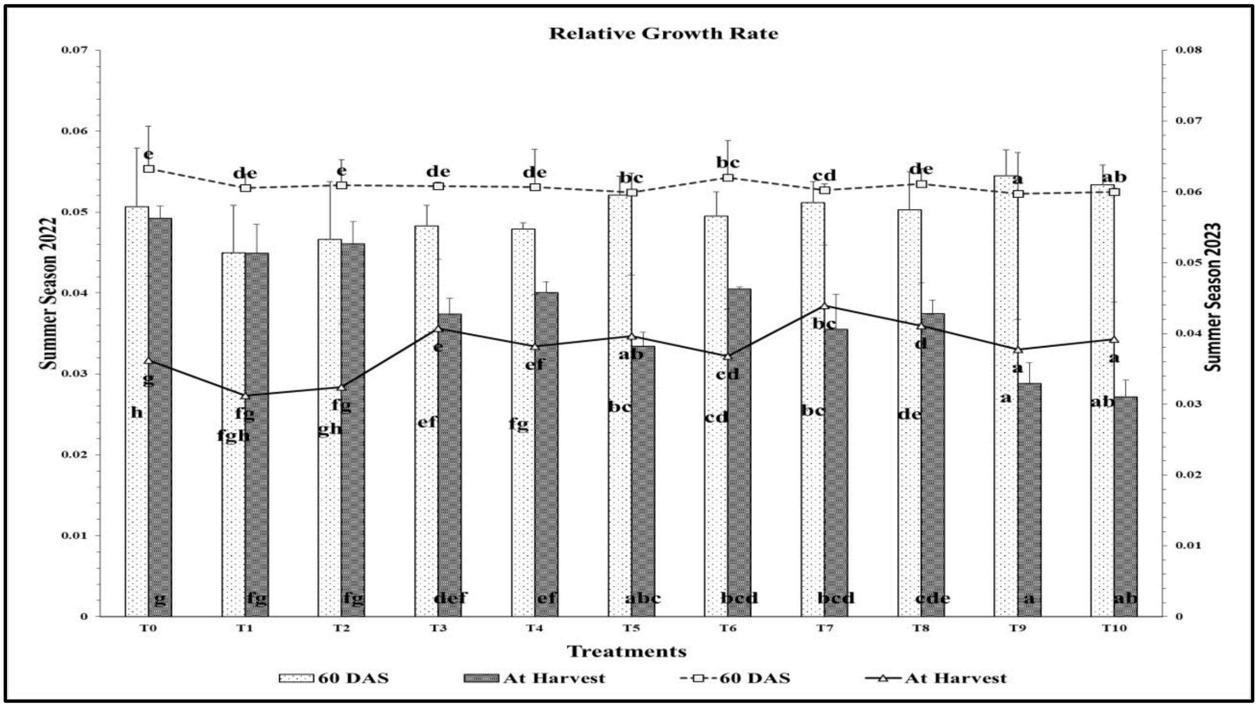


Figure 4.1.12.1a Effect of various treatments on relative growth rate (g/g/day) of mung bean at 60 DAS and at harvest during *Summer* season 2022-23

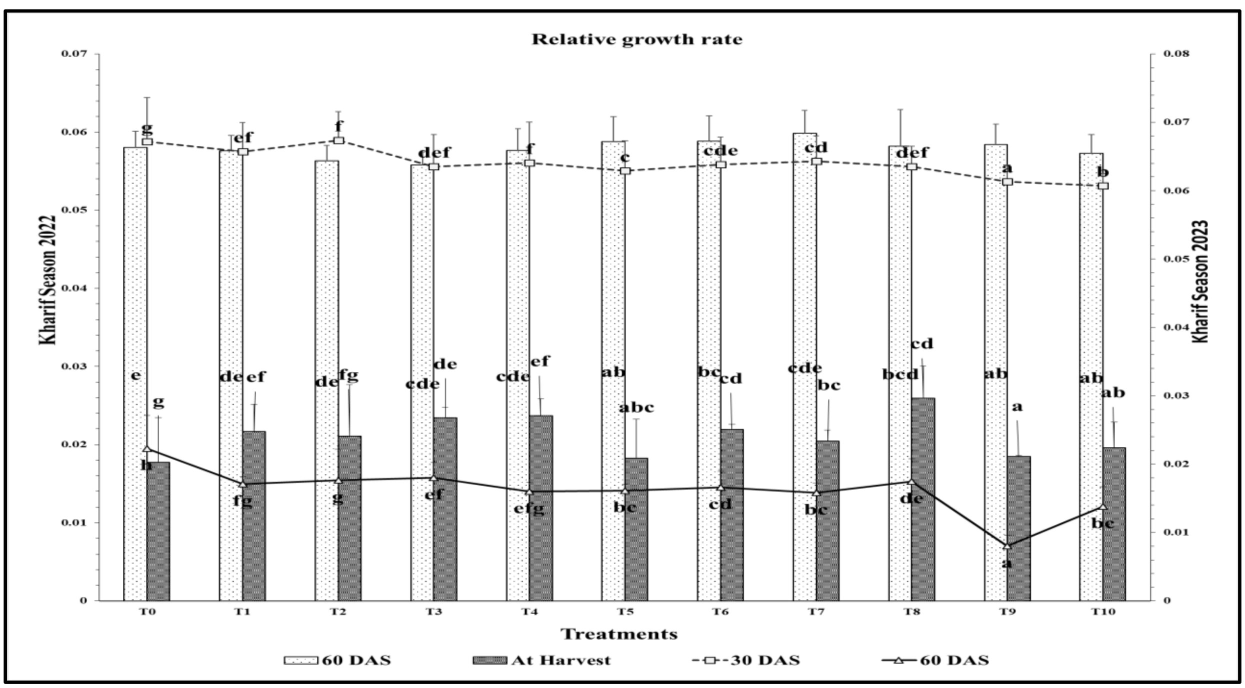


Figure 4.1.12.2a Effect of various treatments on relative growth rate (g/g/day) of mung bean at 60 DAS and at harvest during *Kharif* season 2022-23

4.1.13 Net Assimilation Rate (g/cm^2/day)

The effect of seed priming with gibberellin, salicylic acid and foliar application of zinc and boron on net assimilation rate was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of net assimilation rate was recorded at 60 DAS (Table 4.1.13.1, 4.1.13.2 and Figure 4.1.13.1a and Figure 4.1.13.2a). The NAR was significant at 60-DAS. However, the maximum and minimum net assimilation ratio 1.15 g/cm^2/day and 0.79 g/cm^2/day were recorded by treatment T9 and T1 respectively. In *Summer* 2023 the net assimilation ratio was non-significant at 60 DAS. However, the maximum and minimum net assimilation ratio 1.10 g/cm^2/day and 1.07 g/cm^2/day were recorded by treatment T4, T5, T6 and T2 respectively.

Table 4.1.13.1 Effect of various treatments on net assimilation rate (g/cm^2/day) of mung bean at 60 DAS during *Summer* season 2022 and 2023

Treatments	Net assimilation rate *Summer* 2022	Net assimilation rate *Summer* 2023
	60 DAS	60 DAS
T0	1.97^{e}±0.06	2.62^{a}±0.12
T1	1.91^{e}±0.00	2.63^{a}±0.05
T2	1.93^{e}±0.09	2.56^{a}±0.03
T3	2.11^{de}±0.05	2.51^{a}±0.07
T4	2.11^{de}±0.08	2.63^{a}±0.14
T5	2.58^{ab}±0.04	2.63^{a}±0.00
T6	2.32^{cd}±0.06	2.66^{a}±0.07
T7	2.51^{bc}±0.01	2.63^{a}±0.08
T8	2.33^{cd}±0.04	2.63^{a}±0.06
T9	2.80^{a}±0.04	2.63^{a}±0.05
T10	2.71^{ab}±0.08	2.61^{a}±0.02
CD	0.098	NS
SE(m)	0.033	0.043

In *Kharif* 2022 the net assimilation ratio was non-significant at 60 DAS. However, the maximum and minimum net assimilation ratio 1.07 g/cm^2/day and 0.98 g/cm^2/day were recorded by treatment T9 and T3 respectively. In *Kharif* 2023 it was recorded that the net assimilation ratio was non-significant at 60 DAS. However, the maximum and minimum net assimilation ratio 1.12 g/cm^2/day and 1 g/cm^2/day were recorded by treatment T9 and T0 respectively. *Kharif* 2023 exhibited a more restricted range of NAR values compared to *Kharif* 2022, suggesting less variability in net assimilation during the later season.. NAR tends to be higher during the early growth stages when leaves are most efficient at photosynthesis. As the plant matures and leaf senescence starts, net assimilation rate (NAR) typically declines. Various environmental, genetic, and methodological factors can result in non-significant NAR findings. Different mung bean cultivars may exhibit varying NARs due to genetic differences, with some cultivars not showing significant differences even under similar conditions. Soil conditions and moisture levels also influence plant growth and NAR, and inconsistent soil conditions across test plots can lead to non-significant differences in NAR. The similar results were obtained by **Gong *et al.,* 2022; Amitrano *et al.,* 2021; Chaudhary *et al.,* 2023.**

Table 4.1.13.2 Effect of various treatments on net assimilation rate (g/cm^2/day) of mung bean at 60 DAS during *Kharif* season 2022 and 2023

Treatments	**Net assimilation rate *Kharif* 2022**	**Net assimilation rate *Kharif* 2023**
	60 DAS	**60 DAS**
T0	2.07^a±0.01	2.08^a±0.08
T1	2.14^a±0.07	2.18^a±0.07
T2	2.07^a±0.03	2.15^a±0.06
T3	2.06^a±0.04	2.19^a±0.06
T4	2.12^a±0.01	2.22^a±0.08
T5	2.22^a±0.08	2.30^a±0.14
T6	2.13^a±0.02	2.27^a±0.02
T7	2.17^a±0.06	2.31^a±0.02
T8	2.15^a±0.07	2.26^a±0.05
T9	2.24^a±0.06	2.35^a±0.04
T10	2.18^a±0.09	2.25^a±0.01
CD	NS	NS
SE(m)	0.031	0.039

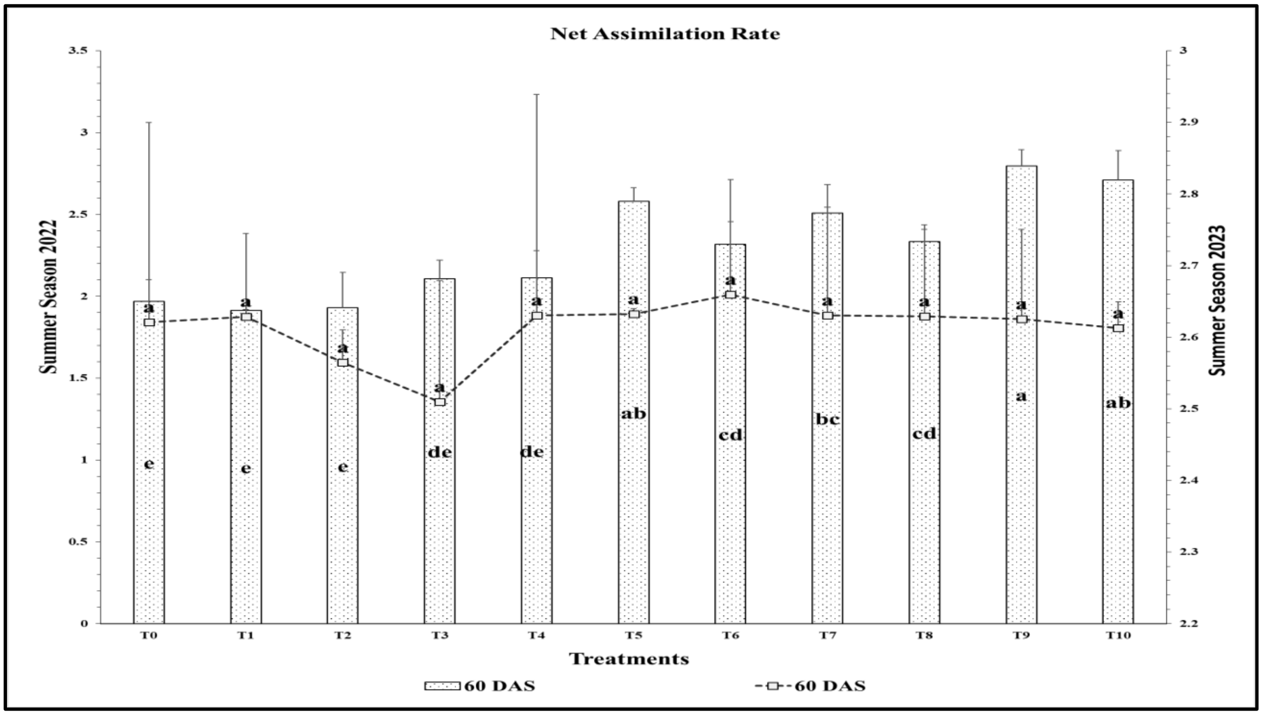


Figure 4.1.13.1a Effect of various treatments on net assimilation ratio (g/cm^2/day) of mung bean at 60 DAS during *Summer* season 2022

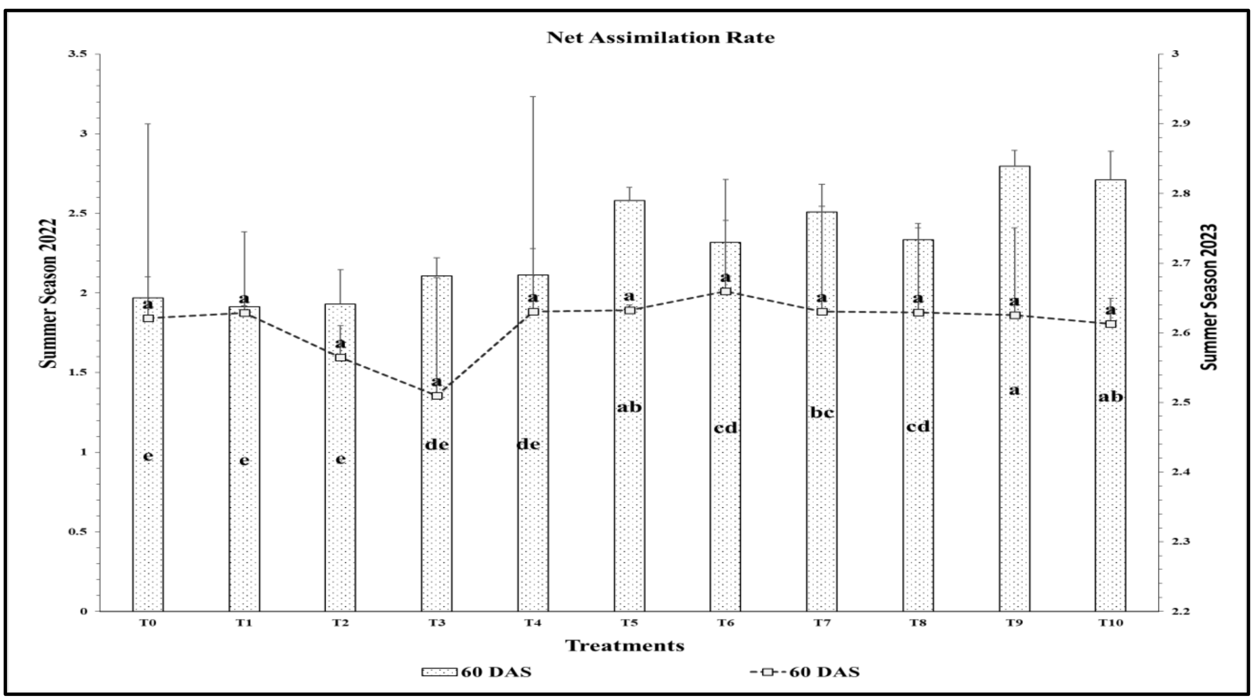


Figure 4.1.13.2a Effect of various treatments on net assimilation rate (g/cm^2/day) of mung bean at 60 DAS during *Kharif* season 2022

4.2 Biochemical parameters from mung bean leaves at 30 and 60 DAS

4.2.1 Chlorophyll a (mg/g Fresh Weight)

The effect of seed priming with gibberellin, salicylic acid or micronutrient foliar application on chlorophyll a (mg/g Fresh Weight) was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of chlorophyll a (mg/g Fresh Weight) was note at 30, 60 DAS intervals (Table 4.2.1.1, 4.2.1.2 and Figure 4.2.1.1a and Figure 4.2.1.2a). In 2022 and 2023, there was a significant difference in the % of chlorophyll a (mg/g Fresh Weight) by phytohormones priming and foliar application of micronutrients. In *Summer* 2022, it was recorded that the maximum chlorophyll a was found in T9 (5.02) followed by T10 (4.51) at 60 DAS. The minimum chlorophyll a was found in control (T0) (3.30) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and it was found at par with single phytohormones priming i.e. T1 and T2. The percentage of chlorophyll a (mg/g Fresh Weight) was increased in T9 by 76.3% at 30 DAS and 52.1% 60 DAS respectively as compared to the treatment T0. It was also observed that percentage of chlorophyll a (mg/g Fresh Weight) was lowest in (T2) i.e. 23.6% and 17.1% at 30 and 60 DAS respectively when compared with treatment (T7) i.e. zinc (Zn) foliar application in salicylic acid primed seed plants. In *Summer* 2023 it was recorded that the maximum chlorophyll a was found in T9 (4.42) followed by T10 (4.34) at 60 DAS. The minimum chlorophyll a was found in control (T0) (3.39) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and it was found at par with single phytohormones priming T2. The percentage of chlorophyll a (mg/g Fresh Weight) was significantly increased in treatment T9 (i.e. combined foliar application of Zinc and boron in gibberellin primed seed plants) 98.7% at 30 DAS and 30.4% at 60 DAS when compared to treatment T0. Similarly, it was found that the treatment T7 enhanced the percentage of chlorophyll a (mg/g Fresh Weight) by 17.2% and 11.5% at 30 and 60 DAS respectively when compared with treatment T3 (i.e. individual foliar application zinc). It was also observed that percentage of chlorophyll a (mg/g Fresh Weight) was lowest in treatment (T1) (i.e. individual application of gibberellin primed seeds) i.e. 26.5% and 12.9% at 30 and 60 DAS respectively when compared with treatment (T6). When comparing *Summer* 2022 to *Summer* 2023, the chlorophyll a content in *Summer* 2023 was slightly lower than in *Summer* 2022 but still significantly influenced by similar treatments. The percentage increases in chlorophyll a were more pronounced in *Summer* 2023, particularly for T9, highlighting its effectiveness across both years.

Table 4.2.1.1 Effect of various treatments on chlorophyll a (mg/g fresh weight) in mung bean at 30 and 60 DAS during *Summer* season 2022 and 2023

	Chlorophyll a (mg/g fresh weight) *Summer* 2022 and *Summer* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	1.31^{h}±0.03	0.77^{f}±0.06	3.30^{g}±0.06	3.39^{h}±0.06
T1	1.40^{gh}±0.04	0.83^{ef}±0.07	3.45^{fg}±0.06	3.64^{fg}±0.04
T2	1.37^{gh}±0.02	0.82^{ef}±0.03	3.40^{g}±0.04	3.54^{g}±0.05
T3	1.53^{f}±0.07	0.93^{d}±0.03	3.70^{e}±0.11	3.73^{f}±0.08
T4	1.44^{fg}±0.02	0.86^{de}±0.03	3.56^{f}±0.03	3.66^{fg}±0.09
T5	1.93^{c}±0.08	1.25^{b}±0.03	4.44^{b}±0.13	4.26^{bc}±0.01
T6	1.68^{de}±0.06	1.05^{c}±0.05	4.01^{cd}±0.10	4.11^{de}±0.09
T7	1.73^{d}±0.07	1.09^{c}±0.05	4.108^{c}±0.12	4.16^{cd}±0.16
T8	1.63^{e}±0.03	1.01^{c}±0.07	3.92^{d}±0.05	3.97^{e}±0.05
T9	2.31^{a}±0.04	1.53^{a}±0.02	5.02^{a}±0.07	4.42^{a}±0.09
T10	2.02^{b}±0.05	1.31^{b}±0.04	4.51^{b}±0.08	4.34^{ab}±0.08
CD (at p≤ 0.05)	0.08	0.08	0.13	0.14
SEm (±)	0.03	0.03	0.04	0.05

In *Kharif* 2022 the percentage of chlorophyll a (mg/g Fresh Weight) was significantly increased in treatment T10 (i.e. combined Zinc and boron (B) foliar application in salicylic acid primed seed plants) 56.7% and 27.5% at 30-days and 60-DAS respectively as compared to control (T0). It was also observed that percentage of chlorophyll a (mg/g Fresh Weight) was lowest in treatment (T4) i.e. 3.9% and 6.4% at 30, and 60 DAS respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023 it was recorded that the percentage of chlorophyll a (mg/g Fresh Weight) was increased in T10 by 68.5% at 30-DAS and 26.7% at 60-DAS when compared to the treatment T0 (i.e. control). It was also observed that percentage of chlorophyll a (mg/g Fresh Weight) was lowest in control (T3) i.e. 34.5% and 12.6% at 30 and 60 DAS respectively when compared with treatment (T5) i.e. foliar application of zinc in gibberellin primed seed plants. Comparing *Kharif* 2022 to *Kharif* 2023, both years showed significant effects of treatments on chlorophyll a content. The percentage increases were generally higher in *Kharif* 2023, particularly for T10, indicating a possibly greater effectiveness of the combined treatments in the later season. Overall, T10 consistently performed well across both seasons. Application of GA_3 enhanced the chlorophyll content in leaves might be due to enhanced cell division and increased chloroplast development in the plant that may contribute in improving chlorophyll content in leaves. These results are in accordance with those of **Islam *et al.*, 2021; Hasan *et al.*, 2020; Ahmad *et al.*, 2022.** Foliar applications of zinc sulfate at a concentration of 50 mg · L−1 have shown beneficial effects on chlorophyll levels. It is well-established that micronutrients like Fe^{2+}, Mn^{2+}, Cu^{2+}, and Zn^{2+} play a key role in activating various metabolic enzymes, which are involved in the biosynthesis of proteins and chlorophyll. Similar results were obtained by **Souri *et al.*, 2019; Aghaye-Noroozlo *et al.*, 2019; Ghidan *et al.*, 2020; Ragab *et al.*, 2022; Qian *et al.*, 2024**). The combined foliar application of zinc and boron increases the chlorophyll content in leaves due to zinc which acts as a structural or catalytic proteins component, enzymes and as co-factor for the normal development of pigment biosynthesis. These results are in agreement with **Kanwal *et al.*, 2020; Hussain *et al.*, 2023.**

Table 4.2.1.2 Effect of various treatments on chlorophyll a (mg/g fresh weight) in mung bean at 30 and 60 DAS during *Kharif* season 2022 and 2023

	Chlorophyll a (mg/g fresh weight) *Kharif* 2022 and *Kharif* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	0.90^{h}±0.02	0.73^{j}±0.01	3.60^{h}±0.05	3.15^{f}±0.04
T1	1.00^{f}±0.06	0.81^{hi}±0.01	3.86^{f}±0.06	3.40^{e}±0.08
T2	0.95^{g}±0.01	0.78^{ij}±0.00	3.76^{g}±0.02	3.25^{f}±0.08
T3	1.04^{ef}±0.02	0.87^{gh}±0.02	3.95^{f}±0.06	3.48^{e}±0.07
T4	1.03^{ef}±0.03	0.85^{h}±0.05	3.89^{f}±0.06	3.42^{e}±0.06
T5	1.34^{b}±0.02	1.17^{c}±0.01	4.43^{bc}±0.04	3.92^{bc}±0.09
T6	1.14^{d}±0.02	0.97^{ef}±0.05	4.28^{d}±0.10	3.82^{c}±0.06
T7	1.18^{c}±0.02	1.01^{d}±0.02	4.33^{cd}±0.08	3.87^{bc}±0.08
T8	1.07^{e}±0.04	0.93^{fg}±0.03	4.14^{e}±0.01	3.68^{d}±0.04
T9	1.43^{a}±0.04	1.45^{a}±0.08	4.59^{a}±0.08	4.14^{a}±0.06
T10	1.41^{a}±0.02	1.23^{b}±0.06	4.47^{b}±0.06	3.99^{b}±0.05
CD (at p≤ 0.05)	0.04	0.06	0.09	0.11
SEm (±)	0.01	0.02	0.03	0.04

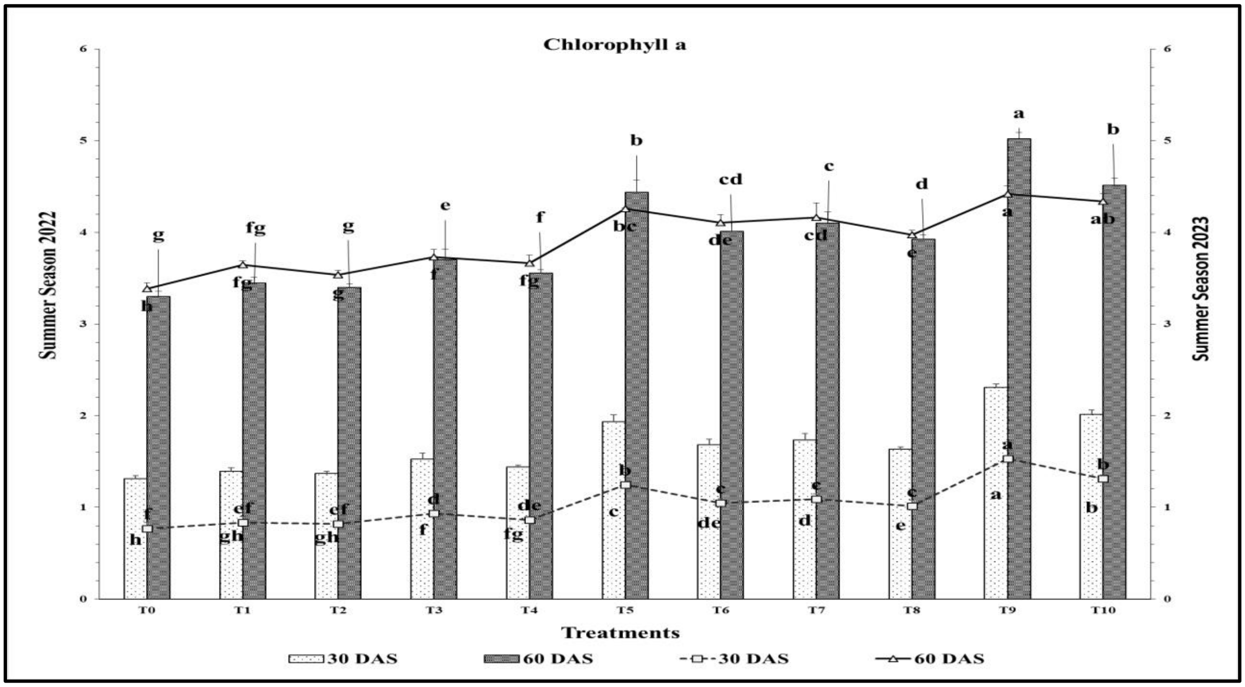


Figure 4.2.1.1a Effect of various treatments on chlorophyll a (mg/g fresh weight) in mung bean at 30 and 60 DAS during *Summer* season 2022-23

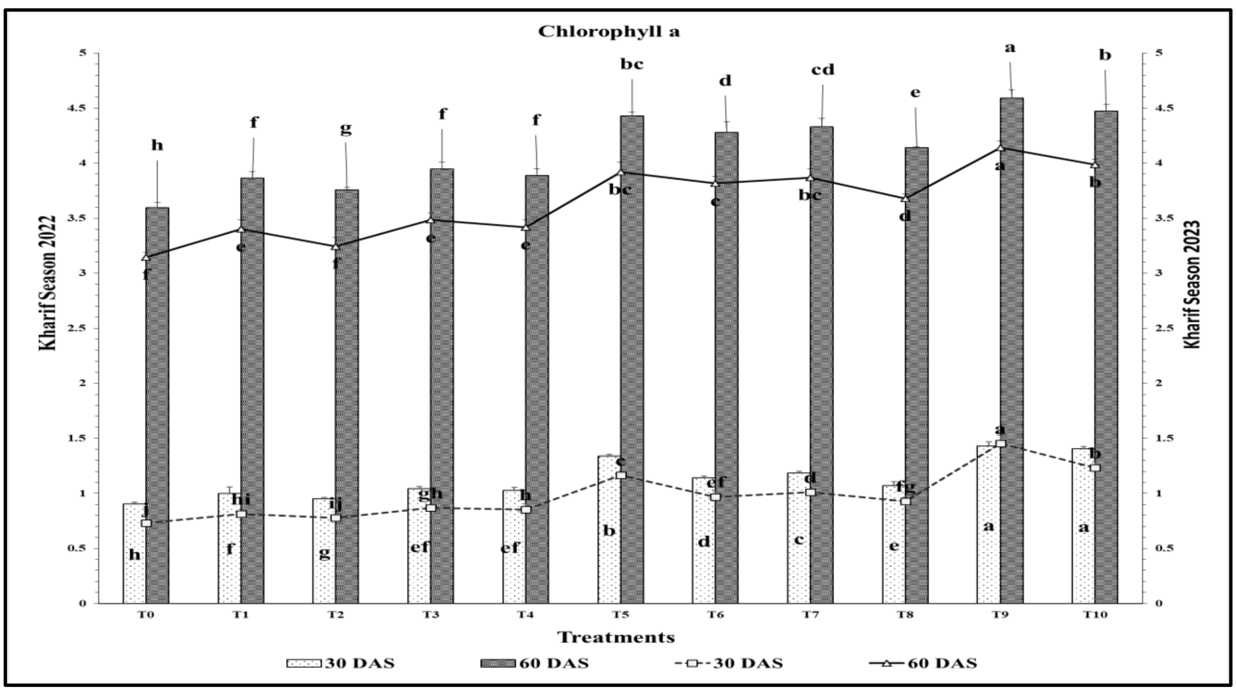


Figure 4.2.1.2a Effect of various treatments on chlorophyll a (mg/g fresh weight) in mung bean at 30 and 60 DAS during *Kharif* season 2022-23

4.2.2 Chlorophyll b (mg/g Fresh Weight)

The effect of seed priming with gibberellin, SA (salicylic acid) and foliar application of zinc and boron on chlorophyll b (mg/g Fresh Weight) was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of chlorophyll b (mg/g Fresh Weight) was noted at 30, 60 DAS intervals (Table 4.2.2.1, 4.2.2.2 and Figure 4.2.2.1a and Figure 4.2.2.2a). In 2022 and 2023, there was a significant difference in the percentage of chlorophyll b (mg/g Fresh Weight) by phytohormones priming and foliar application of micronutrients. In *Summer* 2022, it was recorded that the maximum chlorophyll b was found in T9 (1.66) followed by T10 (1.55) at 60 DAS. The minimum chlorophyll b was found in control (T0) (0.98) which was significantly lower than priming with phytohormone and micronutrients combined foliar application and it was found at par with single phytohormones priming T2. The percentage of chlorophyll b (mg/g Fresh Weight) was increased in T9 by 53.7% at 30 DAS and 33.9% at 60 when compared to the control T0. It was also observed that percentage of chlorophyll b (mg/g Fresh Weight) was lowest in (T2) i.e. 24.2% and 17.6% at 30 and 60 DAS respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. In *Summer* 2023 the percentage of chlorophyll b (mg/g Fresh Weight) was significantly increased in treatment T9 (i.e. combined foliar application of Zinc and boron in gibberellin primed seed plants) 94.9% at 30-DAS and 69.4% at 60-DAS respectively as compared to treatment (T0) control. Similarly, it was found that the treatment T7 enhanced the percentage of chlorophyll b (mg/g Fresh Weight) by 23.5% and 23.9% at 30-days and 60-DAS respectively when compared with treatment T3 (i.e. individual foliar application zinc). It was also observed that percentage of chlorophyll b (mg/g Fresh Weight) was lowest in treatment (T1) (i.e. individual application of gibberellin primed seeds) i.e. 28% and 15.6% at 30-days and 60-DAS respectively when compared with treatment (T6). Comparing the two *Summer*s, *Summer* 2023 had a generally lower absolute chlorophyll b content than *Summer* 2022. However, the percentage increases from control in *Summer* 2023 were higher, particularly for T9, suggesting that while the absolute values were lower, the relative effectiveness of treatments was greater in 2023

Table 4.2.2.1 Effect of various treatments on chlorophyll b (mg/g fresh weight) in mung bean at 30 and 60 DAS during *Summer* season 2022 and 2023

	Chlorophyll b (mg/g fresh weight) *Summer* 2022 and *Summer* 2023			
	30 DAS		60 DAS	
Treatments	2022	2023	2022	2023
T0	1.21^{f}±0.09	0.79^{f}±0.09	2.30^{g}±0.12	0.98^{f}±0.11
T1	1.36^{de}±0.07	0.93^{de}±0.03	2.51^{ef}±0.09	1.09^{def}±0.03
T2	1.27^{ef}±0.06	0.86^{ef}±0.07	2.38^{fg}±0.08	1.06^{ef}±0.09
T3	1.37^{de}±0.06	0.98^{cd}±0.06	2.57^{de}±0.09	1.17^{def} ±0.13
T4	1.36^{de}±0.06	0.96^{cde}±0.04	2.56^{de}±0.08	1.23^{cde} ±0.07
T5	1.57^{b} ±0.08	1.21^{b}±0.08	2.85^{bc}±0.11	1.45^{b}±0.18
T6	1.57^{b} ±0.05	1.19^{b}±0.05	2.88^{b} ±0.07	1.26^{cd}±0.06
T7	1.58^{b} ±0.05	1.21^{b}±0.05	2.89^{b} ±0.07	1.45^{b}±0.13
T8	1.45^{c}±0.06	1.07^{c}±0.06	2.71^{cd}±0.08	1.38^{bc}±0.06
T9	1.86^{a}±0.07	1.54^{a}±0.05	3.08^{a}±0.10	1.66^{a}±0.07
T10	1.57^{b} ±0.07	1.22^{b}±0.06	2.72^{cd} ±0.09	1.55^{ab}±0.09
CD (at p≤ 0.05)	0.1	0.1	0.15	0.17
SEm (±)	0.03	0.03	0.05	0.06

In *Kharif* 2022 the percentage of chlorophyll b (mg/g Fresh Weight) was significantly increased in treatment T10 40.4% at 30 DAS and 38.8% at 60 respectively as compared to treatment (T0) control. It was also observed that percentage of chlorophyll b (mg/g Fresh Weight) was lowest in treatment (T4) i.e. 21% and 7.6% at 30, and 60 DAS respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023, it was recorded that the maximum chlorophyll b was found in T9 (1.37) followed by T10 (1.29) at 60 DAS. The minimum chlorophyll b was found in control (T0) (0.72) which was significantly lower than priming with phytohormone and micronutrient combined foliar application, it was found at par with single phytohormones priming T1. The percentage of chlorophyll b (mg/g Fresh Weight) was increased in T10 by 91.5% at 30DAS respectively as compared to the control T0. It was also observed that percentage of chlorophyll b (mg/g Fresh Weight) was lowest in control (T3) i.e. 34.8% and 24% at 30 and 60 DAS respectively when compared with treatment (T5) i.e. foliar application of zinc in gibberellin primed seed plants. Similarly, it was found that the treatment T8 enhanced the percentage of chlorophyll b (mg/g Fresh Weight) by 37% at 30 and decreased 6% at 60 DAS when compared with treatment T2 i.e. priming of seeds with salicylic acid. Comparing *Kharif* 2022 to *Kharif* 2023, both seasons showed significant effects of treatments on chlorophyll b. *Kharif* 2023 had higher chlorophyll b levels than *Kharif* 2022, especially in T9 and T10. The percentage increase from control was also higher in 2023, indicating that the treatments had a more pronounced effect in the later season. Both the *Summer* and *Kharif* season crop of mung bean chlorophyll b (mg/g Fresh Weight) was slightly greater in *Summer* season as we compare to *Kharif* season, chlorophyll b (mg/g Fresh Weight) in the crop of *Summer* season was higher. Seed priming with GA_3 in mung beans is expected to enhance seed germination rates, promote early seedling growth, and increase chlorophyll b content in the leaves, thereby boosting photosynthetic efficiency and raising the total chlorophyll content. Similar results were obtained by **Islam *et al.*, 2023; Abdelhamid *et al.,* 2019.** The interaction between zinc and boron can have a synergistic effect on plant growth and development. For example, boron can enhance the mobility of zinc in the plant (**Liu *et al.*, 2022)**. Boron also enhanced the utilization of zinc in the plant, leading to the improvement of overall health and chlorophyll a or b content in mung bean plant leaves. The analogous results are obtained by **Bautista *et al.*, 2021; Gahlot *et al.,* 2020; Dhaliwal et al., 2023.**

Table 4.2.2.2 Effect of various treatments on chlorophyll b (mg/g fresh weight) in mung bean at 30 and 60 DAS during *Kharif* season 2022 and 2023

	Chlorophyll b (mg/g fresh weight) *Kharif* 2022 and *Kharif* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	1.04^{d}±0.05	0.47^{e}±0.06	1.46^{f}±0.02	0.72^{e}±0.07
T1	1.16^{cd}±0.04	0.75^{c}±0.09	1.57^{ef}±0.10	0.84^{de}±0.19
T2	1.11^{cd}±0.06	0.54^{de}±0.06	1.53^{ef}±0.13	1.17^{b}±0.10
T3	1.23^{c}±0.03	0.66^{cd}±0.07	1.70^{de}±0.05	0.96^{cd}±0.04
T4	1.19^{c}±0.06	0.62^{cd}±0.07	1.71^{de}±0.12	0.97^{cd}±0.13
T5	1.46^{b} ±0.05	0.89^{b}±0.09	1.90^{bc}±0.07	1.19^{b}±0.11
T6	1.44^{b} ±0.05	0.87^{b}±0.05	1.71^{de}±0.12	0.97^{cd}±0.13
T7	1.46^{b} ±0.05	0.89^{b}±0.05	1.91^{bc}±0.09	1.17^{b}±0.08
T8	1.44^{b} ±0.06	0.74^{c}±0.08	1.84^{cd}±0.13	1.10^{bc}±0.08
T9	1.77^{a}±0.16	1.22^{a}±0.09	2.12^{a}±0.05	1.37^{a}±0.03
T10	1.46^{b} ±0.03	0.90^{b}±0.07	2.02^{ab}±0.12	$1.^{29ab}$±0.06
CD (at p≤ 0.05)	0.1	0.12	0.15	0.18
SEm (±)	0.03	0.04	0.05	0.06

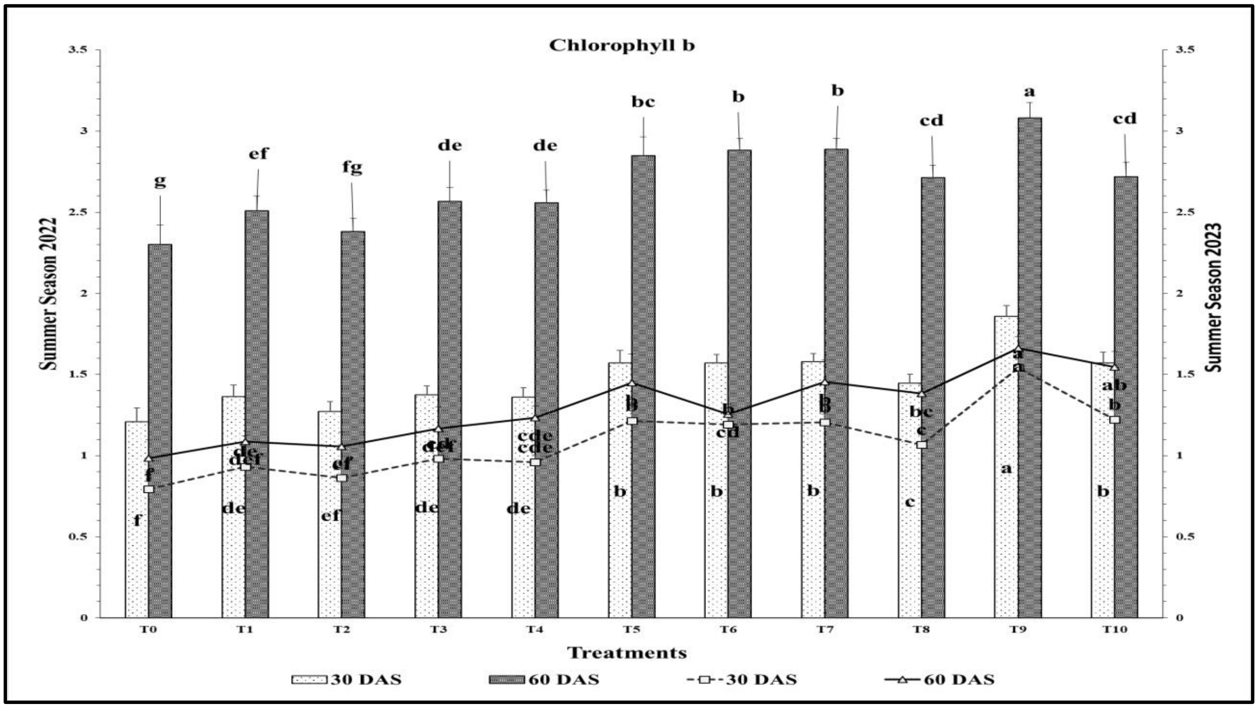


Figure 4.2.2.1a Effect of various treatments on chlorophyll b (mg/g fresh weight) in mung bean at 30 and 60 DAS during *Summer* season 2022-23

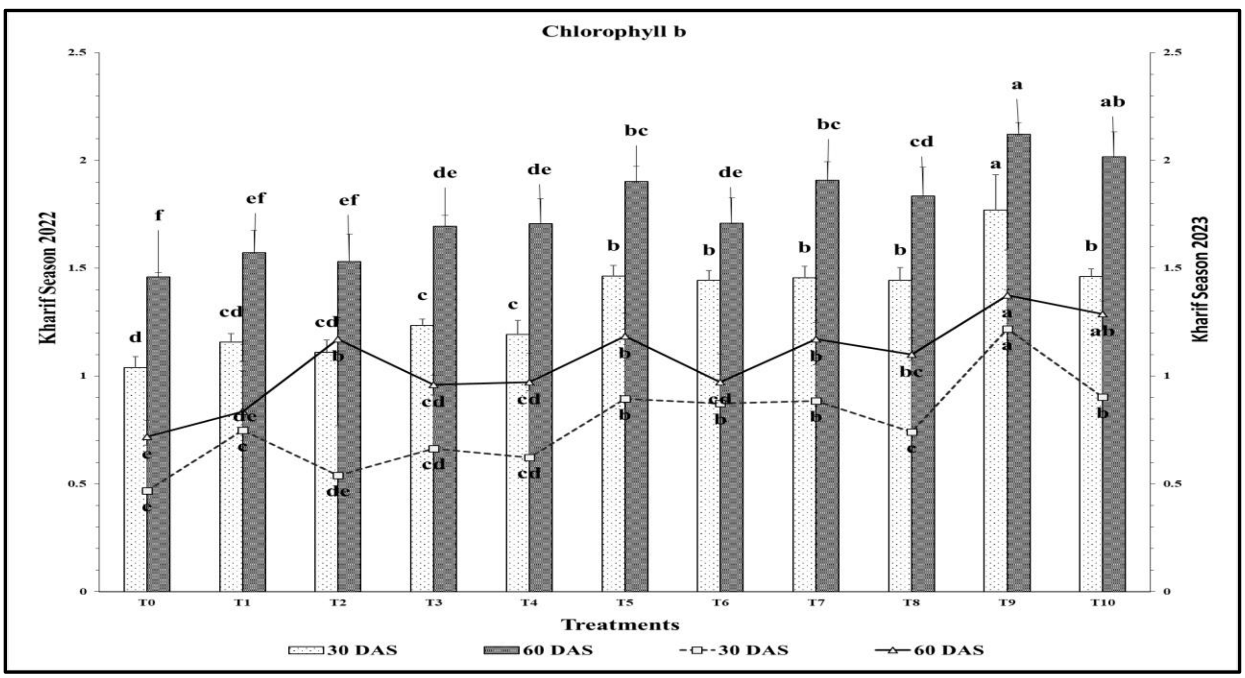


Figure 4.2.2.2a Effect of various treatments on chlorophyll b (mg/g fresh weight) in mung bean at 30 and 60 DAS during *Kharif* season 2022-23

4.2.3 Ratio of chlorophyll a and b

The effect of seed priming with gibberellin, salicylic acid and micronutrients foliar application on chlorophyll a and b ratio was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of chlorophyll a and b ratio was recorded at 30-days, 60-DAS intervals (Table 4.2.3.1, 4.2.3.2 and and Figure 4.2.3.1a and Figure 4.2.3.2a). In 2022 and 2023, there was a significant difference in the percentage of chlorophyll a and b ratio by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that the maximum chlorophyll a ratio b was found in T10 (1.66) followed by T9 (1.63) at 60 DAS. The minimum chlorophyll a ratio b was found in (T1) (1.37). The percentage of chlorophyll a and b ratio was increased in treatment T9 by 2.5% and 13.2% at 30-days and 60-DAS respectively as compared to the T0 (control). It was also observed that percentage of chlorophyll a and b ratio was increases in (T2) i.e. 1.9% at 30 DAS and decreases 0.7 % at 60 DAS when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants.. In *Summer* 2023, it was recorded that the maximum chlorophyll a ratio b was found in control T0 (3.48) followed by T1, T2 (3.36) at 60 DAS. The minimum chlorophyll a ratio b was found in (T9) (2.66). The percentage of chlorophyll a and b ratio was decreased in treatment (T0) 2% at 30 and increased 23.6% at 60 DAS as compared to T9 (i.e. combined foliar application of Zinc and boron in gibberellin primed seed plants). It was found that the treatment T3 (i.e. individual foliar application zinc) enhanced the percentage of chlorophyll a and b ratio by 4.2% and 10.8% at 30 and 60 DAS respectively when compared with treatment T7. It was also observed that %of chlorophyll a and b ratio was lowest in treatment (T1) i.e. 1.1% and 2.4% at 30 and 60 DAS respectively when compared with treatment (T6). Comparing the two *Summer*s, *Summer* 2023 showed a generally higher chlorophyll a to b ratio than *Summer* 2022. This is especially notable in the control and treatments like T1 and T2, which had higher ratios in *Summer* 2023 compared to *Summer* 2022. The percentage changes in the ratio from control were more variable, indicating differing effects of treatments across the two years.

Table 4.2.3.1 Effect of various treatments on ratio of chlorophyll a and b in mung bean at 30 and 60 DAS during *Summer* season 2022 and 2023

	Ratio of Chlorophyll a and b *Summer* 2022 and *Summer* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	1.09^{c}±0.08	0.98^{ab}±0.14	1.44^{b}±0.08	3.48^{ab}±0.43
T1	1.02^{c}±0.04	0.89^{b}±0.07	1.37^{b}±0.03	3.36^{ab}±0.13
T2	1.08^{c}±0.04	0.95^{ab}±0.09	1.43^{b}±0.03	3.36^{ab}±0.32
T3	1.11^{c}±0.09	0.95^{ab}±0.09	1.45^{b}±0.09	3.23^{abc}±0.40
T4	1.06^{c}±0.03	0.90^{b}±0.01	1.39^{b}±0.03	2.98^{abc}±0.20
T5	1.23^{ab}±0.09	1.03^{ab}±0.07	1.56^{a}±0.09	2.97^{abc}±0.36
T6	1.07^{c}±0.05	0.88^{b}±0.05	1.39^{b}±0.05	3.28^{a}±0.22
T7	1.10^{c}±0.06	0.91^{b}±0.06	1.42^{b}±0.06	2.88^{abc}±0.39
T8	1.13^{bc}±0.03	0.95^{ab}±0.11	1.45^{b}±0.03	2.98^{abc}±0.14
T9	1.24^{a}±0.06	1.00^{ab}±0.04	1.63^{a}±0.07	2.66^{c}±0.07
T10	1.28^{a}±0.05	1.08^{a}±0.05	1.66^{a}±0.06	2.82^{bc}±0.23
CD (at p≤ 0.05)	0.11	0.13	0.11	0.46
SEm (±)	0.04	0.05	0.04	0.16

In *Kharif* 2022 the percentage of chlorophyll a and b ratio was increased in treatment T10 i.e. 10.3 at 30 DAS and decreases 9.8% 60 DAS as compared to control (T0). It was also observed that percentage of chlorophyll a and b ratio was lowest in treatment (T4) i.e. 0.9% at 60 DAS when compared with treatment (T8). In *Kharif* 2023 it was recorded that the percentage of chlorophyll a and b ratio was increased in control (T0) by 12.7% at 30-DAS and 29.5% at 60-DAS respectively as compared to the treatment T10. It was also observed that percentage of chlorophyll a and b ratio was lowest in control T5 i.e. foliar application of zinc in gibberellin primed seed plants i.e. 0.8% and 0.9% at 30 and 60 DAS respectively when compared with treatment (T3). Comparing *Kharif* 2022 to *Kharif* 2023, *Kharif* 2023 demonstrated a higher chlorophyll a to b ratio in the control and some treatments compared to *Kharif* 2022. The percentage changes from control were more pronounced in *Kharif* 2023, suggesting more significant effects of treatments on the chlorophyll a to b ratio in the later season. The variations between treatments in *Kharif* 2023 were more substantial, particularly for T10 and T5, indicating different responses across the two *Kharif* seasons. Both the *Summer* and *Kharif* season crop of mung bean chlorophyll a and b ratio was slightly greater in *Summer* season as we compare to *Kharif* season, chlorophyll a and b ratio in the crop of *Summer* season was higher. SA priming often leads to an increase in total chlorophyll content, potentially altering the Chl a/b ratio. This adjustment can improve the light-harvesting efficiency and balance between the photosystems **(Lotfi *et al.,* 2020)**. GA can modulate the Chl a/b ratio by promoting the synthesis of chlorophyll a and b, thus potentially optimizing the balance for efficient photosynthesis. The results are supported by **Ahmad *et al.,* 2022; Islam *et al*., 2023.** Sufficient zinc supply can boost levels of both chlorophyll a and b, potentially achieving an optimal Chl a/b ratio that enhances light absorption and energy transfer within the photosystems. Boron may indirectly influence chlorophyll content by promoting overall plant health and nutrient uptake, which can help stabilize the Chl a/b ratio. Efficient light capture and utilization, driven by an optimal Chl a/b ratio, supports improved growth and increased yield (**Ghidan *et al*., 2020)**. **Foliar zinc and boron application** micronutrients support chlorophyll synthesis and stability, contributing to an optimal Chl a/b ratio and better photosynthetic performance. Integrating priming with foliar micronutrients can lead to healthier mung bean plants with improved growth, higher yield, and better quality (**Gul et al., 2019; Bautista *et al*., 2021; Ragab *et al*., 2022)**.

Table 4.2.3.2 Effect of various treatments on ratio of chlorophyll a and b in mung bean at 30 and 60 DAS during *Kharif* season 2022 and 2023

	Ratio of Chlorophyll a and b *Kharif* 2022 and *Kharif* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	0.87^{bc}±0.04	1.57^{a}±0.17	2.46^{a}±0.00	4.40^{a}±0.39
T1	0.93^{c}±0.03	1.09^{c}±0.11	2.47^{ab}±0.17	4.23^{ab}±0.14
T2	0.86^{bc}±0.04	1.45^{ab}±0.17	2.46^{ab}±0.19	2.78^{f}±0.28
T3	0.84^{bc}±0.01	1.32^{abc}±0.14	2.33^{ab}±0.10	3.63^{cd}±0.13
T4	0.86^{c}±0.07	1.39^{abc}±0.26	2.28^{abc}±0.17	3.57^{d}±0.36
T5	0.92^{bc}±0.03	1.31^{abc}±0.12	2.33^{abc}±0.06	3.33^{de}±0.09
T6	0.79^{c}±0.02	1.11^{c}±0.02	2.51^{ab}±0.23	3.97^{bc}±0.07
T7	0.81^{c}±0.02	1.14^{c}±0.04	2.27^{bc}±0.14	3.32^{de}±0.12
T8	0.74^{bc}±0.05	1.27^{bc}±0.18	2.26^{bc}±0.17	3.36^{de}±0.22
T9	0.81^{bc}±0.09	1.20^{bc}±0.13	2.16^{c}±0.02	3.01^{ef}±0.03
T10	0.96^{a}±0.01	1.37^{abc}±0.17	2.22^{bc}±0.13	3.10^{ef}±0.18
CD (at p≤ 0.05)	0.07	0.27	0.24	0.77
SEm (±)	0.02	0.09	0.08	0.26

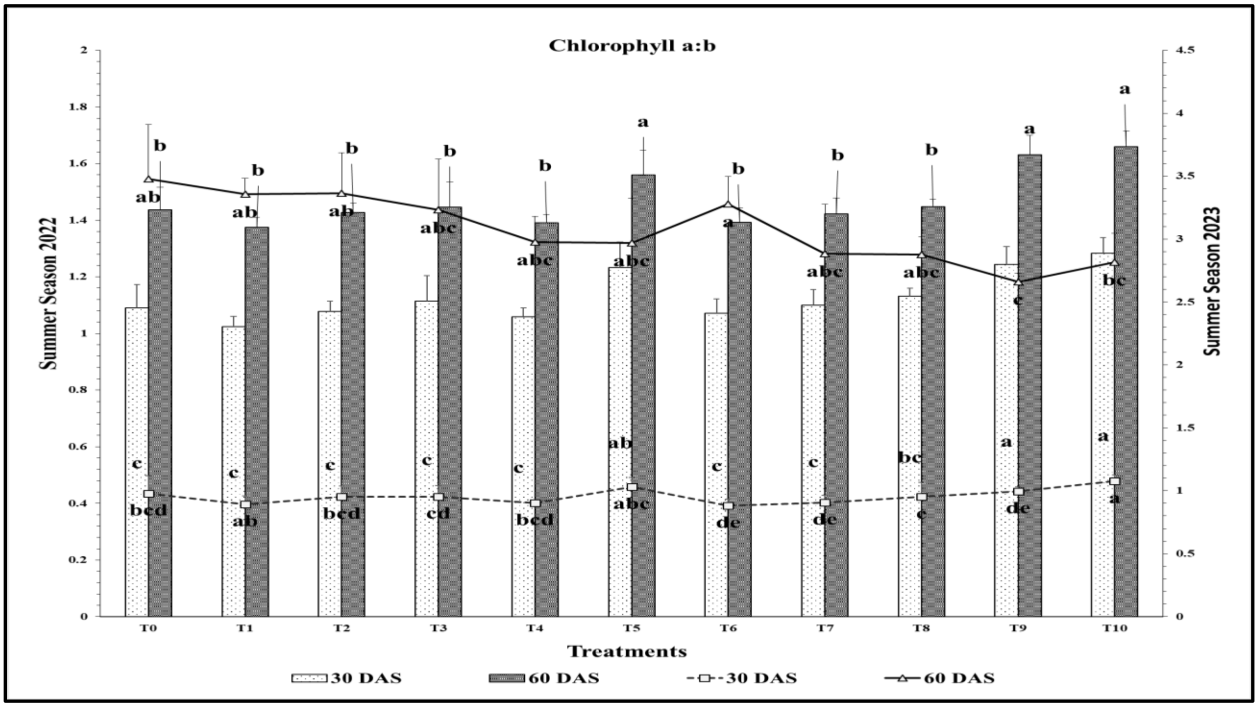


Figure 4.2.3.1a Effect of various treatments on ratio of chlorophyll a and b in mung bean at 30 and 60 DAS during *Summer* season 2022-23

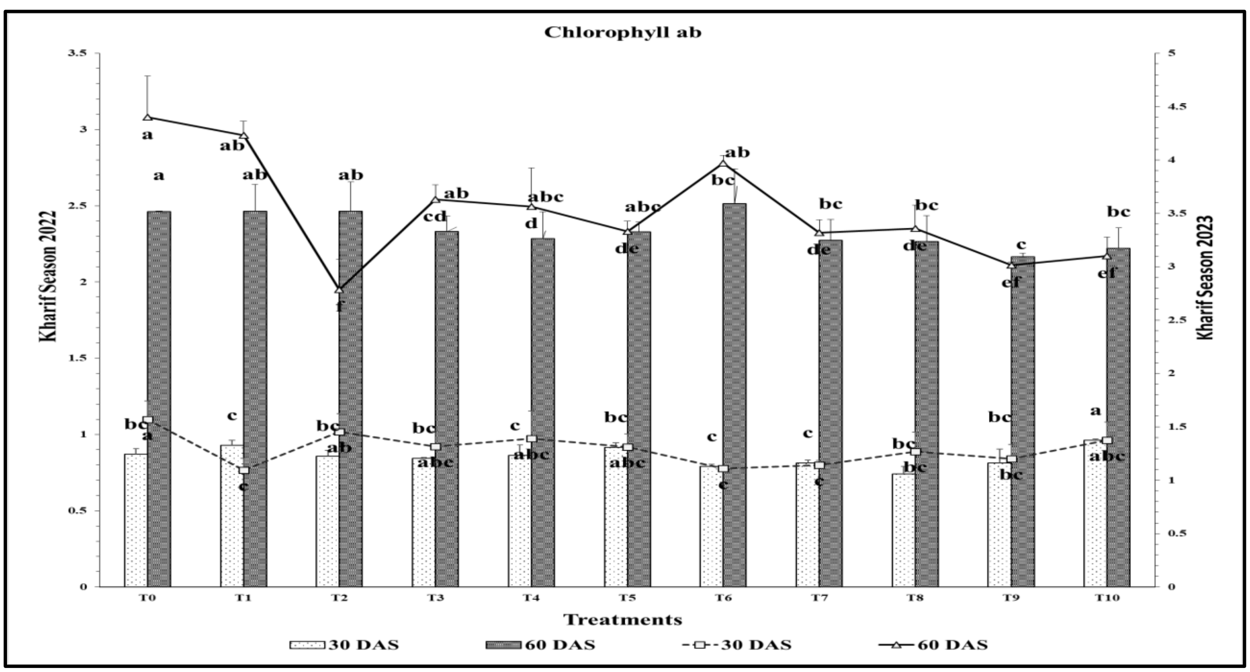


Figure 4.2.3.2a Effect of various treatments on ratio of chlorophyll a and b in mung bean at 30 and 60 DAS during *Kharif* season 2022-23

4.2.4 Chlorophyll index

The effect of priming seeds with gibberellin, salicylic acid and micronutrients foliar application on chlorophyll index was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of chlorophyll index was noted at 30, 60 DAS intervals (Table 4.2.4.1, 4.2.4.2 and Figure 4.2.4.1a and Figure 4.2.4.2a). In 2022 and 2023, there was a significant difference in the % of chlorophyll index by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that that the maximum chlorophyll index was found in T9 (60.97) followed by T10 (58.71) at 60 DAS. The minimum chlorophyll index was found in control (T0) (44.20) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and found at par with single phytohormones priming i.e. T1 and T2. The percentage of chlorophyll index was increased in T9 by 25.1% at 30-DAS and 27.5% at 60-DAS when compared to the control T0. It was also observed that percentage of chlorophyll index was lowest in (T2) i.e. 15.1% and 13.8% at 30 and 60 DAS respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. Similarly, it was found that the treatment T6 (i.e. foliar application of boron in Gibberellin primed seed plants) enhanced the percentage of chlorophyll index by 5.3% and 7.2% at 30 and 60 DAS respectively when compared with treatment T4 i.e. individual foliar application of boron. In *Summer* 2023 the percentage of chlorophyll index was significantly increased in treatment T9 (i.e. combined foliar application of micronutrients (Zn+B) in gibberellin primed seed plants) 26.7% at 30-DAS and 26.1% at 60-DAS respectively as compared to control (T0). It was also observed that percentage of chlorophyll index was lowest in treatment T1 (i.e. individual application of gibberellin primed seeds) 11% and 13.9% at 30 and 60-DAS respectively when compared with treatment (T6). Comparing the two *Summer*s, the chlorophyll index was generally higher in *Summer* 2022 compared to *Summer* 2023. In 2023, while T9 and T10 remained among the highest, the percentage increases from the control were smaller. The variability in the chlorophyll index across different treatments was more pronounced in *Summer* 2022.

Table 4.2.4.1 Effect of various treatments on chlorophyll index in mung bean at 30 and 60 DAS during *Summer* season 2022 and 2023

	Chlorophyll Index *Summer* 2022 and *Summer* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	$39.42^{d}\pm4.53$	$35.31^{e}\pm1.40$	$44.2^{f}\pm3.20$	$40.8^{f}\pm1.92$
T1	$42.36^{cd}\pm2.27$	$37.58^{de}\pm2.63$	$47.89^{ef}\pm3.91$	$42.16^{ef}\pm3.32$
T2	$41.41^{d}\pm2.61$	$36.96^{de}\pm2.76$	$47.59^{ef}\pm2.70$	$41.86^{ef}\pm2.04$
T3	$45.53^{abcd}\pm5.00$	$40.75^{bcd}\pm2.54$	$51.93^{cde}\pm2.99$	$46.2^{de}\pm2.29$
T4	$44.2^{bcd}\pm4.43$	$39.42^{cde}\pm1.97$	$50.77^{de}\pm2.99$	$45.37^{def}\pm1.94$
T5	$49.45^{abc}\pm5.00$	$45^{ab}\pm3.09$	$56.75^{abc}\pm2.58$	$51.02^{abc}\pm2.02$
T6	$46.68^{abcd}\pm3.01$	$42.23^{bc}\pm2.34$	$54.69^{bcd}\pm2.29$	$48.96^{bcd}\pm1.91$
T7	$48.8^{abc}\pm3.75$	$44.35^{ab}\pm2.79$	$55.22^{bcd}\pm3.44$	$49.49^{bcd}\pm3.13$
T8	$46.47^{abcd}\pm4.33$	$42.02^{bc}\pm2.41$	$53.96^{bcd}\pm2.08$	$48.23^{cd}\pm1.70$
T9	$52.6^{a}\pm3.20$	$48.16^{a}\pm2.73$	$60.97^{a}\pm3.28$	$55.23^{a}\pm2.79$
T10	$51.34^{ab}\pm2.91$	$46.9^{a}\pm1.27$	$58.71^{ab}\pm3.94$	$52.98^{ab}\pm3.64$
CD (at $p\leq 0.05$)	5.05	3.91	5.44	4.39
SEm (±)	1.7	1.32	1.83	1.46

In *Kharif* 2022 the percentage of chlorophyll index was significantly increased in treatment T10 (i.e. combined Zinc and boron (B) foliar application in salicylic acid primed seed plants) 25.6% at 30-DAS and 26.9% at 60-DAS respectively as compared to control (T0). It was also observed that percentage of chlorophyll index was lowest in treatment (T4) i.e. 7.2% and 8% at 30, and 60 DAS respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023 it was recorded that that the maximum chlorophyll index was found in T9 (54.20) followed by T10 (51.97) at 60 DAS. The minimum chlorophyll index was found in control (T0) (39.77) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and found at par with single phytohormones priming i.e. T1 and T2. The percentage of chlorophyll index was increased in T10 by 3% at 30-DAS and

23.4% at 60-DAS respectively as compared to the control T0. It was also observed that percentage of chlorophyll index was lowest in control (T3) i.e. 10.8% and 9.6% at 30-DAS and 60-DAS respectively when compared with treatment (T5) i.e. foliar application of zinc in gibberellin primed seed plants. Comparing *Kharif* 2022 and 2023, the chlorophyll index in *Kharif* 2023 was generally lower than in *Kharif* 2022. While T9 and T10 were still among the top treatments in 2023, the percentage increases were less dramatic. The variability in treatment effects was less pronounced in *Kharif* 2023 compared to 2022. Both the *Summer* and *Kharif* season crop of mung bean chlorophyll index was slightly greater in *Summer* season as we compare to *Kharif* season, chlorophyll index in the crop of *Summer* season was higher. GA priming combined with foliar applications of zinc and boron can significantly improve the chlorophyll index in mung bean leaves. The increase in chlorophyll content enhances photosynthetic efficiency and overall physiological health. GA can elevate chlorophyll levels in leaves by promoting the synthesis of chlorophyll and associated pigments. This is accomplished by upregulating genes involved in chlorophyll biosynthesis and improving nutrient uptake efficiency. The obtained results are in line with the findings of **Islam *et al.,* 2021; Karamany *et al.,* 2019; Gong *et al.,* 2022.** Zinc is an essential micronutrient that plays a important role in different enzymatic and physiological functions in plants. It is a component of several enzymes involved in chlorophyll production, such as carbonic anhydrase and RNA polymerase. Foliar application of zinc can directly provide the necessary nutrients to the leaves, improving chlorophyll synthesis and hence the chlorophyll index. The results are supported by **Hussain *et al.,* 2021; Zahrani *et al.,* 2021.** By enhancing nutrient mobility and utilization, boron can improve overall plant health and vitality, which is reflected in higher chlorophyll content in leaves. Adequate boron availability ensures the proper functioning of physiological processes that contribute to chlorophyll production. Similar results were obtained by **Haider *et al.,* 2021; Solanki 2021; Sasane *et al.,* 2023; Zafar *et al.,* 2023.**

Table 4.2.4.2 Effect of various treatments on chlorophyll index in mung bean at 30 and 60 DAS during *Kharif* season 2022 and 2023

	Chlorophyll Index *Kharif* 2022 and *Kharif* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	37.58^{e}±3.54	33.99^{e}±2.07	42.33^{f}±2.71	39.77^{e}±2.32
T1	40.52^{de}±1.30	36.26^{cd}±3.28	46.02^{ef}±3.42	41.13^{e}±3.72
T2	39.56^{de}±1.67	35.65^{cd}±3.43	45.72^{ef}±2.20	40.82^{e}±2.42
T3	43.69^{cd}±4.01	38.98^{bcd}±3.38	50.06^{cde}±2.49	45.17^{cde}±2.69
T4	42.36^{cde}±3.44	38.11^{bcd}±2.66	48.9^{de}±2.49	44.34^{de}±2.34
T5	48.63^{abc}±4.00	43.69^{ab}±3.78	55.92^{abc}±2.09	49.99^{abc}±2.42
T6	45.86^{bcd}±2.08	41.1^{abc}±3.09	53.86^{bcd}±1.84	47.93^{bcd}±2.28
T7	47.98^{abc}±3.75	43.04^{ab}±3.49	54.39^{bcd}±2.95	48.46^{bcd}±3.52
T8	45.65^{bcd}±3.33	40.71^{abc}±3.10	53.13^{bcd}±1.59	47.2^{bcd}±2.08
T9	51.78^{a}±2.23	45.99^{a}±3.77	60.14^{a}±2.80	54.2^{a}±3.18
T10	50.52^{ab}±1.97	45.59^{a}±1.97	57.88^{ab}±3.44	51.95^{ab}±4.04
CD (at p≤ 0.05)	3.78	3.56	4.59	2.94
SEm (±)	1.27	1.2	1.55	1

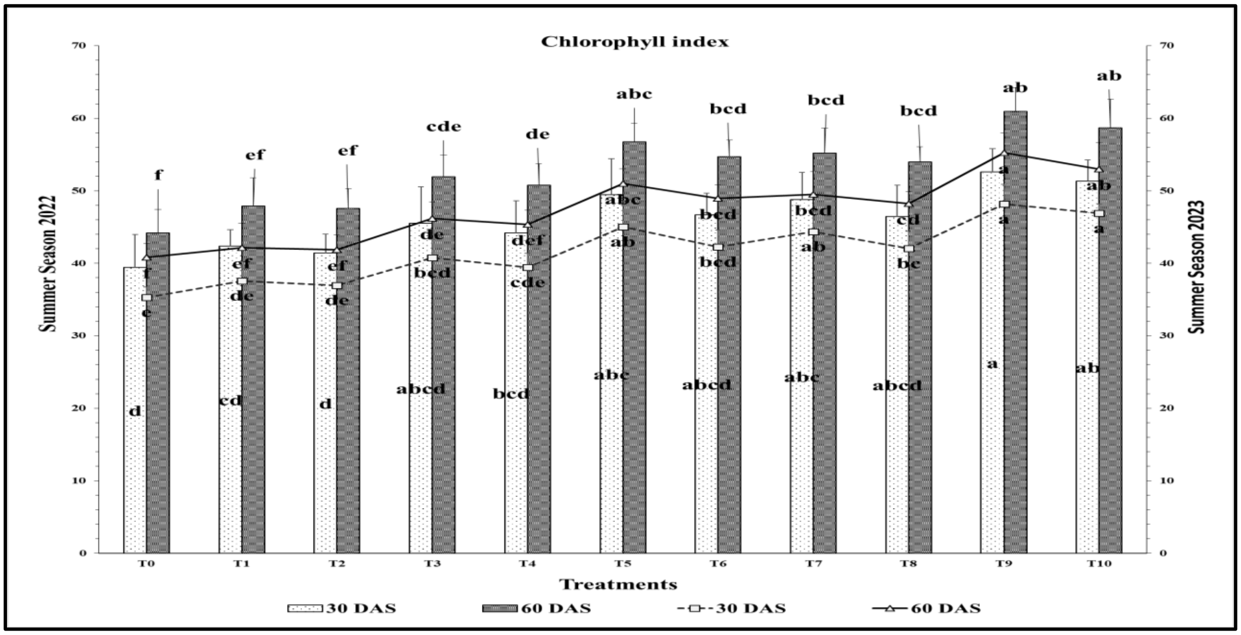


Figure 4.2.4.1a Effect of various treatments on chlorophyll index in mung bean at 30 and 60 DAS during *Summer* season 2022-23

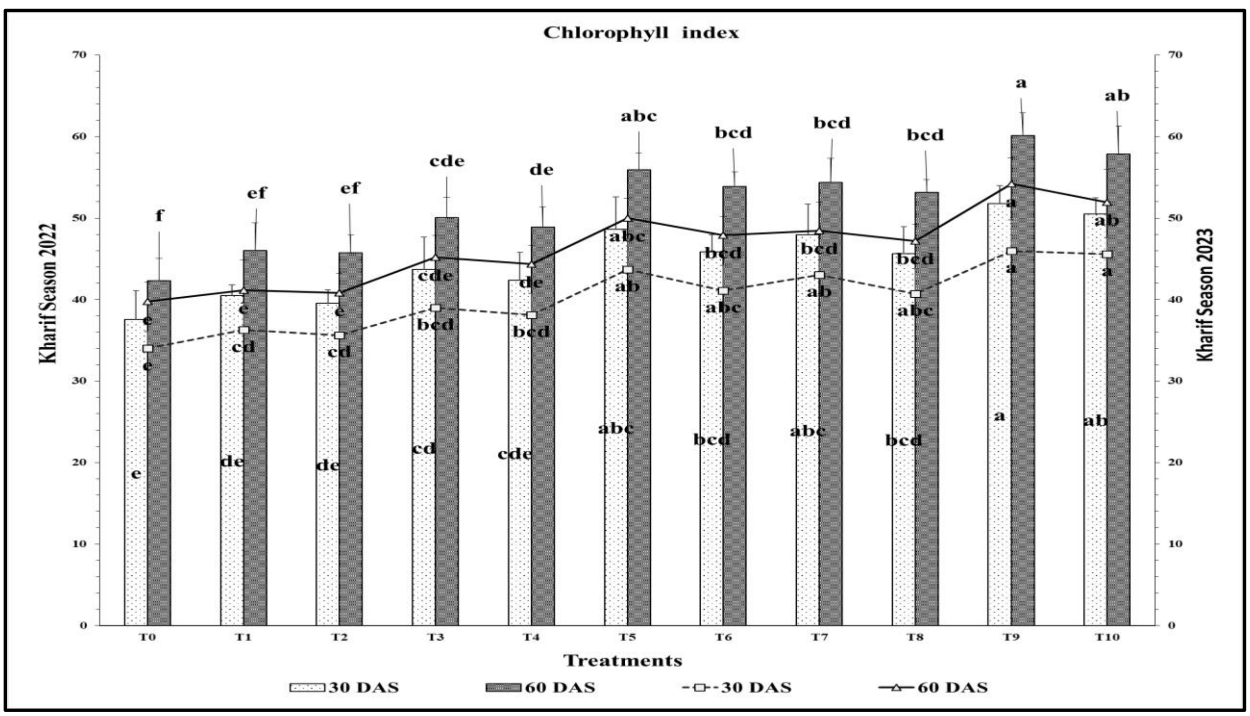


Figure 4.2.4.2a Effect of various treatments on chlorophyll index in mung bean at 30 and 60 DAS during *Kharif* season 2022-23

4.2.5 Total Soluble Sugar (microgram/ml)

The effect of priming seeds with gibberellin, salicylic acid and micronutrients foliar application on total soluble sugar (microgram/ml) was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of total soluble sugar (microgram/ml) was noted at 30, 60 DAS intervals and at harvest (Table 4.2.5.1, 4.2.5.2 and Figure 4.2.5.1a and Figure 4.2.5.2a). In 2022 and 2023, there was a significant difference in the % of total soluble sugar (microgram/ml) by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that that the maximum total soluble sugar was found in T9 (2.34) followed by T10 (2.20) at 60 DAS. The minimum total soluble sugar was found in control (T0) (1.38) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and it was found at par with single phytohormones priming T2. The percentage of total soluble sugar (microgram/ml) was increased in T9 by 35.2% and 41% at 30 and 60 DAS respectively as compared to the control T0. It was also observed that percentage of total soluble sugar (microgram/ml) was lowest in control (T2) i.e. 22.2% and 27.3% at 30 and 60 DAS respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. In *Summer* 2023, it was recorded that that the highest total soluble sugar was found in T9 (2.22) followed by T10 (2.12) at 60 DAS. The minimum total soluble sugar was found in control (T0) (1.29) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and it was found at par with single phytohormones priming T2. The percentage of total soluble sugar (microgram/ml) was significantly increased in treatment T9 (i.e. combined foliar application of Zinc and boron in gibberellin primed seed plants) 35% and 42.3% at 30-daus and 60-DAS respectively as compared to control (T0). It was also observed that percentage of total soluble sugar (microgram/ml) was lowest in treatment (T1) i.e. 41.1% and 45% at 30 and 60 DAS respectively when compared with treatment (T6). Total soluble sugar content was generally higher in *Summer* 2022 compared to *Summer* 2023, although T9 consistently showed the highest values across both years. The percentage increase in total soluble sugar compared to the control was slightly higher in *Summer* 2023, indicating a potentially better response to treatments that year.

Table 4.2.5.1 Effect of various treatments on total soluble sugar (microgram/ml) in mung bean at 30 and 60 DAS during *Summer* season 2022 and 2023

	Total Soluble Sugar (microgram/ml) *Summer* 2022 and *Summer* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	1^{d}±0.05	0.9^{d}±0.06	1.38^{h}±0.07	1.29^{i}±0.06
T1	1.06^{d}±0.06	0.96^{d}±0.11	1.56^{fg}±0.13	1.46^{gh}±0.12
T2	1.05^{d}±0.06	0.97^{d}±0.08	1.52^{gh}±0.05	1.43^{hi}±0.06
T3	1.12^{d}±0.07	1.08^{bcd}±0.03	1.8^{de}±0.06	1.7^{ef}±0.05
T4	1.11^{d}±0.05	1.02^{cd}±0.08	1.7^{ef}±0.09	1.6^{fg}±0.08
T5	1.4^{b}±0.06	1.23^{ab}±0.19	2.1^{bc}±0.08	2^{bc}±0.19
T6	1.28^{ab}±0.09	1.27^{ab}±0.07	1.96^{cd}±0.08	1.87^{cd}±0.08
T7	1.38^{b}±0.11	1.21^{abc}±0.09	2.1^{bc}±0.20	1.95^{cd}±0.04
T8	1.24^{c}±0.07	1.25^{ab}±0.16	1.89^{d}±0.08	1.79^{de}±0.07
T9	1.56^{a}±0.06	1.37^{a}±0.20	2.34^{a}±0.05	2.22^{ab}±0.02
T10	1.4^{b}±0.04	1.42^{a}±0.08	2.2^{ab}±0.06	2.12^{a}±0.03
CD (at p≤ 0.05)	0.112	0.206	0.145	0.133
SEm (±)	0.04	0.07	0.05	0.04

In *Kharif* 2022 the percentage of total soluble sugar (microgram/ml) was significantly increased in treatment T10 foliar application in salicylic acid primed seed plants) 29.6% at 30 DASand 35.8% at 60 DAS when compared to treatment T0 (i.e. control). Similarly, it was found that the treatment T5 enhanced the percentage of total soluble sugar (microgram/ml) by 26.7% at 30-DAS and 24.6% at 60-DAS intervals respectively when compared with treatment T1. It was also observed that percentage of total soluble sugar (microgram/ml) was lowest in treatment (T4) i.e. 11% and 9.8% at 30, and 60 DAS respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023 it was recorded that the percentage of total soluble sugar (microgram/ml) was increased in T10 by 3% and 32.8% at 30 and 60 DAS respectively as compared to the control T0. It was also observed that percentage of total soluble sugar (microgram/ml) was lowest in control (T3) i.e. 22% and 17.8% at 30 and 60 DAS respectively when compared with treatment (T5) i.e. foliar application of zinc in gibberellin primed seed plants. In *Kharif* 2023, the total soluble sugar content was lower compared to *Kharif* 2022, but T10 consistently had the highest values in both years. The percentage increases compared to the control were more variable, with higher increases observed in *Kharif* 2022. T5 also performed better in *Kharif* 2022 compared to 2023. Priming with GA can lead to increased synthesis and mobilization of carbohydrates, including soluble sugars. This is due to the upregulation of enzymes involved in starch degradation and sugar transport, enhancing the availability of soluble sugars in leaves (**Jeandet e*t al.,* 2022)**. It also enhances enzyme activity related to carbohydrate metabolism. Increased TSS enhances metabolic activities, supporting the nucleic acids, protein synthesis and other essential biomolecules. This is crucial for overall plant growth and development. The similar results are recorded by **Diya *et al.,* 2024**; **Hakla *et al.,* 2021.** Zinc is crucial for carbohydrate metabolism, serving as a cofactor for several enzymes involved in the synthesis and breakdown of carbohydrates. Boron enhances the transport of photosynthates (the products of photosynthesis, including soluble sugars) from leaves to other parts of the plant, ensuring efficient carbohydrate distribution **(Uddin *et al.,* 2021)**. This can lead to increased total soluble sugars (TSS) in leaves, as sugars are efficiently produced and mobilized. Foliar application of micronutrients also improves carbohydrate translocation, which generally results in higher yields by allowing plants to allocate more resources to reproductive structures (**Farooq *et al.,* 2020; Rehman *et al.,* 2022; Ahmed *et al.,* 2021)**.

Table 4.2.5.2 Effect of various treatments on total soluble sugar (microgram/ml) in mung bean at 30 and 60 DAS during *Kharif* season 2022 and 2023

	Total Soluble Sugar (microgram/ml) *Kharif* 2022 and *Kharif* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	0.92^{e}±0.05	0.83^{f}±0.06	1.33^{a}±0.08	1.24^{g}±0.08
T1	0.97^{e}±0.05	0.9^{f}±0.06	1.5^{f}±0.04	1.41^{fg}±0.04
T2	0.96^{e}±0.05	0.89^{f}±0.09	1.43^{fg}±0.08	1.33^{g}±0.08
T3	1.03^{e}±0.06	0.96^{ef}±0.07	1.73^{de}±0.10	1.63^{de}±0.09
T4	1.02^{e}±0.06	0.95^{ef}±0.07	1.66^{e}±0.09	1.57^{ef}±0.09
T5	1.32^{b}±0.07	1.24^{bc}±0.10	2^{abc}±0.04	1.84^{bc}±0.06
T6	1.19^{cd}±0.9	1.12^{cd}±0.10	1.91^{abc}±0.08	1.81^{bcd}±0.08
T7	1.28^{bc}±0.11	1.22^{bcd}±0.10	1.93^{abc}±0.21	1.95^{ab}±0.08
T8	1.15^{d}±0.07	1.08^{de}±0.08	1.84^{cd}±0.07	1.74^{cde}±0.07
T9	1.47^{a}±0.06	1.39^{a}±0.07	2.15^{a}±0.03	2.07^{a}±0.04
T10	1.31^{b}±0.03	1.31^{ab}±0.07	2.07^{ab}±0.06	1.97^{ab} ±0.24
CD (at p≤ 0.05)	0.113	0.141	0.151	0.167
SEm (±)	0.04	0.05	0.05	0.06

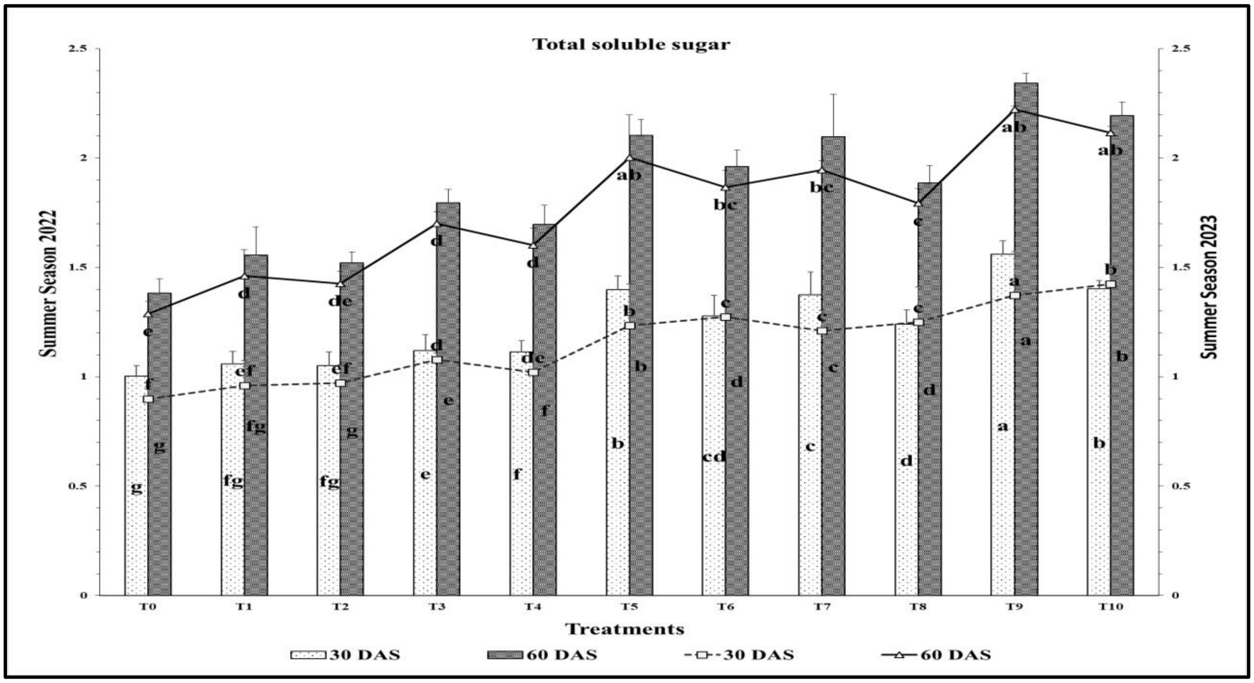


Figure 4.2.5.1a Effect of various treatments on total soluble sugar (microgram/ml) in mung bean at 30 and 60 DAS during *Summer* season 2022

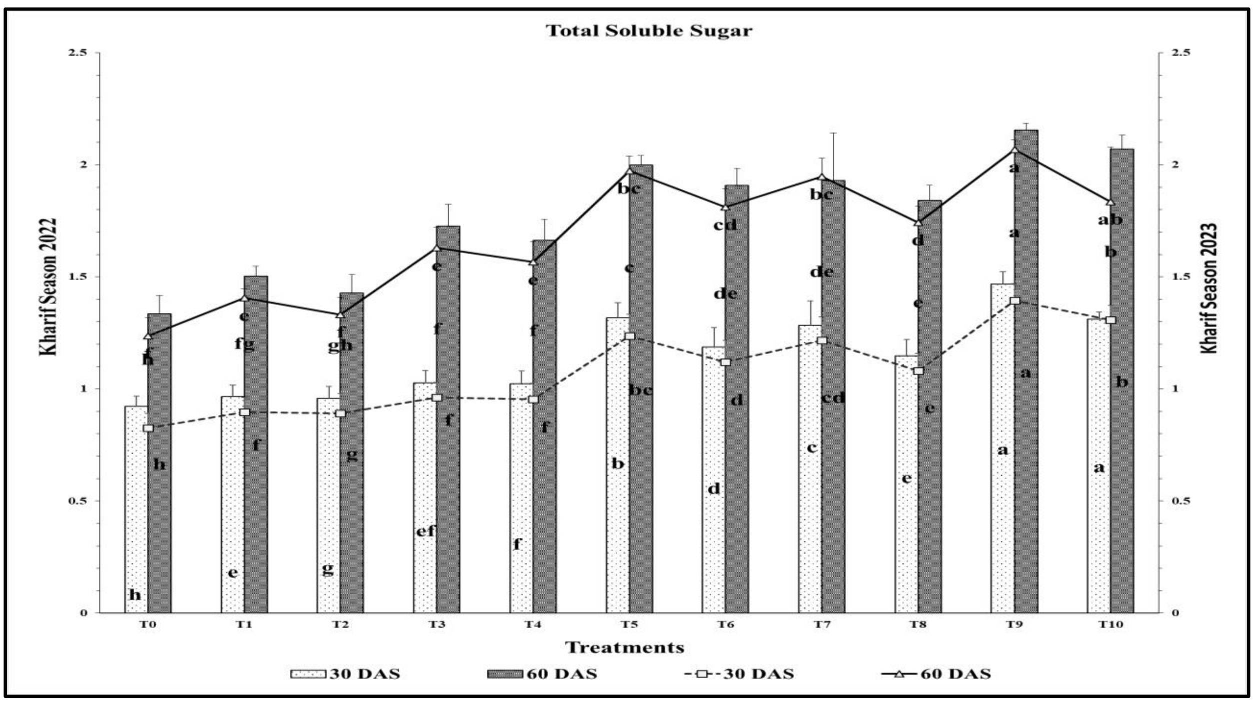


Figure 4.2.5.2a Effect of various treatments on total soluble sugar (microgram/ml) in mung bean at 30 and 60 DAS during *Kharif* season 2022

4.2.6 Total Soluble Protein (microgram/ml)

The effect of priming seeds with gibberellin, salicylic acid and micronutrients foliar application on total soluble protein (microgram/ml) was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of total soluble protein (microgram/ml) was noted at 30, 60 DAS intervals (Table 4.2.6.1, 4.2.6.2 and Figure 4.2.6.1a and Figure 4.2.6.2a). In 2022 and 2023, there was a significant difference in the % of total soluble protein (microgram/ml) by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that the maximum total soluble protein was found in T9 (19.67) followed by T10 (19.44) at 30 DAS. The lowest total soluble protein was found in control (T0) (18.32) which was significantly lower than priming with phytohormone and combined micronutrients foliar application and found at par with single phytohormones priming T2. The percentage of total soluble protein (microgram/ml) was increased in T9 by 6.9% and 9.5% at 30 and 60 DAS respectively as compared to the control T0. It was also observed that percentage of total soluble protein (microgram/ml) was lowest in control (T2) i.e. 5.0% and 7.9% at 30 and 60 DAS respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. In *Summer* 2023 the percentage of total soluble protein (microgram/ml) was significantly increased in treatment T9 7.1% and 10.2% at 30 and 60 DAS respectively as compared to control (T0). Similarly, it was found that the treatment T7 enhanced the percentage of total soluble protein (microgram/ml) by 3.3% and 5.8% at 30 and 60 DAS respectively when compared with treatment T3. It was also observed that percentage of total soluble protein (microgram/ml) was lowest in treatment (T6) i.e. 3.8% and 6.8% at 30 and 60 DAS respectively when compared with treatment (T1). The total soluble protein content was slightly lower in *Summer* 2023 compared to *Summer* 2022, though T9 consistently had the highest values in both years.

Table 4.2.6.1 Effect of various treatments on total soluble protein (microgram/ml) of mung bean at 30 and 60 DAS during *Summer* season 2022 and 2023

	Total Soluble Protein (microgram/ml) *Summer* 2022 and *Summer* 2023			
	30 DAS		60 DAS	
Treatments	2022	2023	2022	2023
T0	18.32^{d}±0.28	17.32^{d}±0.26	12.31^{c}±0.62	11.28^{c}±0.32
T1	18.53^{cd}±0.54	17.52^{d}±0.37	12.46^{bc}±0.66	11.42^{c}±0.36
T2	18.45^{d}±0.73	17.44^{d}±0.29	12.34^{bc}±0.72	11.3^{c}±0.41
T3	18.86^{abcd}±0.27	17.75^{bcd}±0.32	12.67^{abc}±0.58	11.64^{bc}±0.29
T4	18.56^{bcd}±0.47	17.63^{cd}±0.30	12.64^{abc}±0.36	11.67^{bc}±0.26
T5	19.41^{abc}±0.31	18.41^{a}±0.16	13.39^{ab}±0.21	12.36^{a}±0.26
T6	19.13^{abcd}±0.71	18.19^{ab}±0.15	13.23^{abc}±0.58	12.2^{a}±0.11
T7	19.37^{abc}±0.25	18.36^{a}±0.35	13.31^{abc}±0.66	12.36^{a}±0.31
T8	19.02^{abcd}±0.25	18.1^{abc}±0.18	13.11^{abc}±0.36	12.07^{ab}±0.33
T9	19.67^{a}±0.26	18.64^{a}±0.37	13.6^{a}±0.56	12.56^{a}±0.32
T10	19.44^{ab}±0.67	18.41^{a}±0.32	13.39^{ab}±0.46	12.28^{a}±0.18
CD (at $p \leq 0.05$)	0.47	0.21	0.45	0.45
SEm (±)	1.53	1.52	1.59	0.72

In *Kharif* 2022 the percentage of total soluble protein (microgram/ml) was significantly increased in treatment T10 (i.e. combined Zinc and boron (B) foliar application in salicylic acid primed seed plants) 6.3% at 30 DAS and 8.1% at 60 DAS when compared to control (T0). It was also observed that percentage of total soluble protein (microgram/ml) was lowest in treatment (T4) i.e. 2.5% and 3.5% at 30, and 60 DAS respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023 it was recorded that the maximum total soluble protein was found in T9 (18.10) followed by T10 (18.06) at 30 DAS. The lowest total soluble protein was found in treatment (T0) control (16.81) which was significantly lower than priming with phytohormone and combined foliar application of micronutrients and found at par with single phytohormones priming T2. The percentage of total soluble protein (microgram/ml) was increased in T10 by 6.9% and 8.8% at 30 and 60 DAS respectively as compared to the control

T0. It was also observed that percentage of total soluble protein (microgram/ml) was lowest in control (T3) i.e. 3.8% and 6.4% at 30 and 60 DAS respectively when compared with treatment (T5) i.e. foliar application of zinc in gibberellin primed seed plants. Similarly, it was found that the treatment T8 (i.e. foliar application of boron in salicylic acid primed seed plants) enhanced the percentage of total soluble protein (microgram/ml) by 2.4% and 6.3% at 30 and 60 DAS respectively when compared with treatment T2 i.e. individual priming of seeds with salicylic acid. Total soluble protein levels in *Kharif* 2023 were slightly lower compared to *Kharif* 2022. T9 maintained the highest values across both years, with T10 also performing well. Both the *Summer* and *Kharif* season crop of mung bean total soluble protein (microgram/ml) was slightly greater in *Summer* season as we compare to *Kharif* season, total soluble protein (microgram/ml) in the crop of *Summer* season was higher. GA, along with foliar applications of zinc and boron, can significantly enhance the total soluble protein content in mung bean leaves. GA priming can lead to an increase in enzyme activities and protein synthesis pathways, thereby enhancing the overall soluble protein. Zinc ensures direct and efficient uptake by the leaves, enhancing the synthesis of proteins (**Marthandan *et al.,* 2020).** Foliar application of Zinc is essential for the structural integrity of ribosomes. By improving the uptake and utilization of nitrogen, boron enhances amino acid synthesis, which in turn increases the total soluble protein content in leaves. The obtained results are supported by **Islam *et al.,* 2023; Shahzad *et al.,* 2021**. Foliar application of boron also aids in the efficient translocation of sugars and nutrients, which supports overall protein metabolism. Higher levels of soluble proteins in leaves translate to better seed quality with higher protein content, which is a crucial factor for the nutritional value of mung beans. Increased protein synthesis supports robust pod development and seed filling, leading to higher yields (**Naznin *et al.,* 2020**). Proteins are integral to the photosynthetic machinery, including enzymes involved in the Calvin cycle and the structural proteins of the chloroplasts. Increased protein content can thus enhance photosynthetic efficiency and productivity **(Rehman *et al.,* 2022; Khan *et al.,* 2024).**

Table 4.2.6.2 Effect of various treatments on total soluble protein (microgram/ml) of mung bean at 30 and 60 DAS during *Kharif* season 2022 and 2023

	Total Soluble Protein (microgram/ml) *Kharif* 2022 and *Kharif* 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	17.37^{f}±0.25	16.81^{f}±0.34	11.38^{c}±0.29	10.59^{c}±0.20
T1	17.56^{ef}±0.27	17.04^{ef}±0.01	11.53^{c}±0.32	10.76^{c}±0.34
T2	17.55^{ef}±0.33	17.02^{ef}±0.17	11.41^{c}±0.38	10.68^{c}±0.29
T3	17.96^{cde}±0.27	17.27^{de}±0.18	11.74^{bc}±0.26	11.02^{bc}±0.17
T4	17.67^{def}±0.17	17.25^{de}±0.14	11.77^{bc}±0.23	10.99^{bc}±0.20
T5	18.51^{ab}±0.22	17.92^{ab}±0.21	12.46^{a}±0.29	11.72^{a}±0.34
T6	18.2^{bc}±0.17	17.68^{bc}±0.02	12.3^{a}±0.14	11.55^{a}±0.21
T7	18.48^{ab}±0.34	17.84^{ab}±0.35	12.46^{a}±0.31	11.71^{a}±0.26
T8	18.11^{bcd}±0.30	17.44^{cd}±0.16	12.18^{a}±0.31	11.4^{ab}±0.33
T9	18.73^{a}±0.27	18.1^{a}±0.12	12.67^{a}±0.28	11.86^{a}±0.21
T10	18.53^{ab}±0.21	18.06^{a}±0.16	12.38^{a}±0.20	11.61^{a}±0.26
CD (at p≤ 0.05)	0.43	0.31	0.45	0.46
SEm (±)	1.52	1.57	1.47	1.06

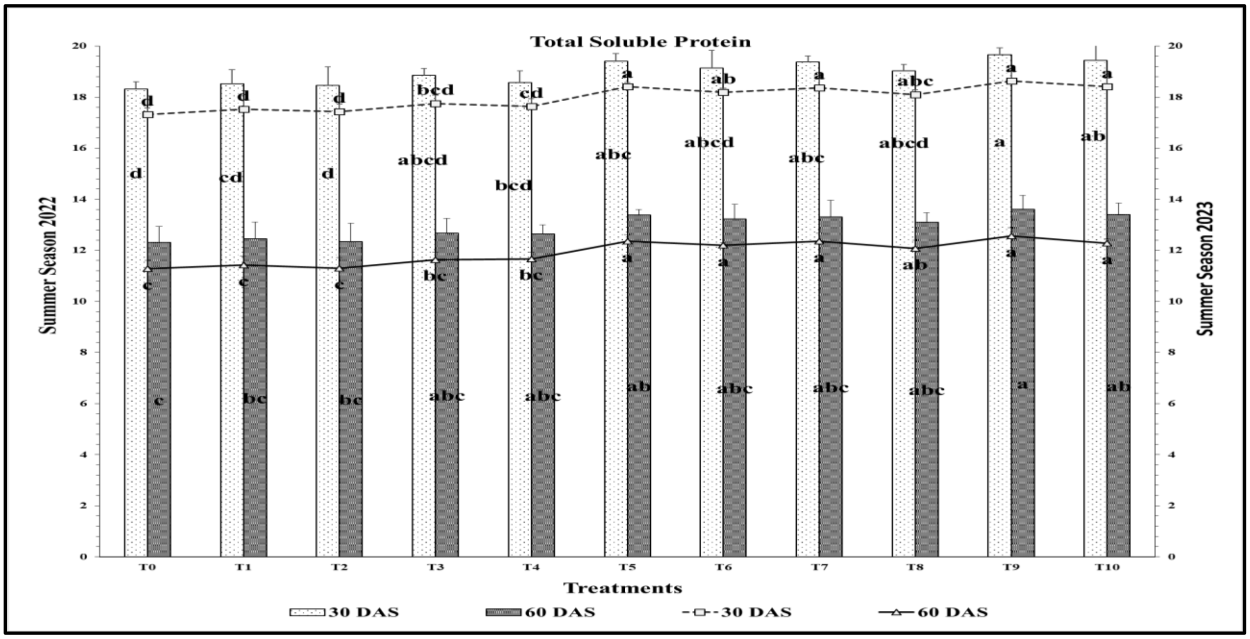


Figure 4.1.6.1a Effect of various treatments on total soluble protein (microgram/ml) of mung bean at 30 and 60 DAS during *Summer* season 2022-23

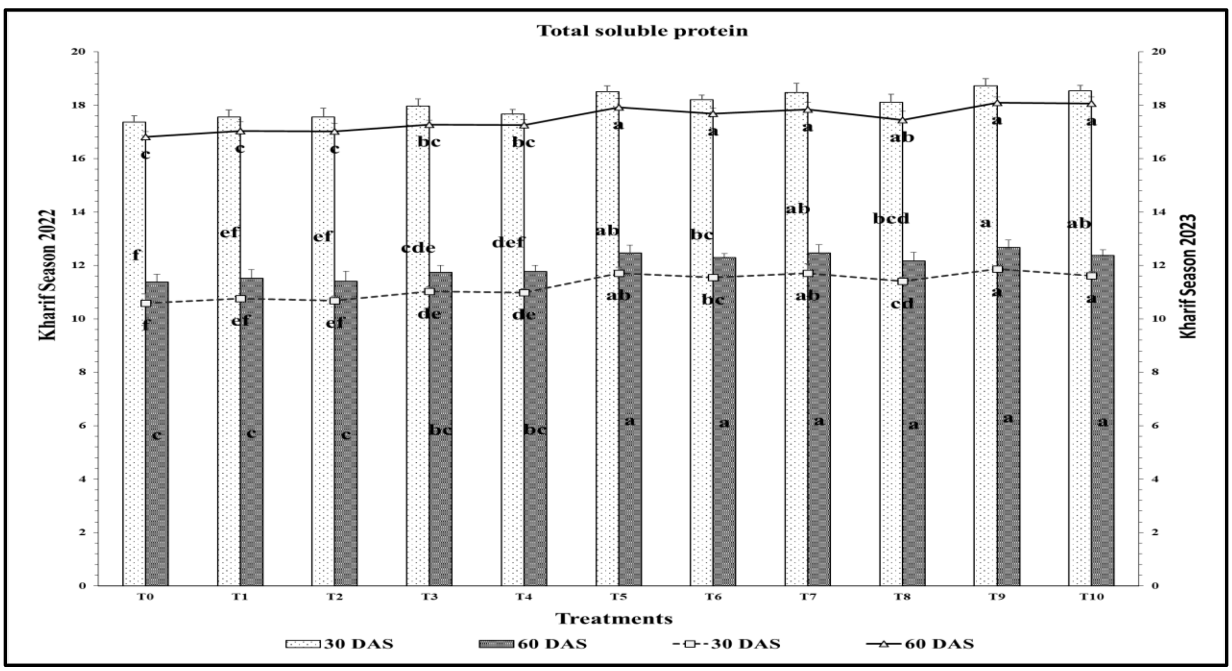


Figure 4.1.6.2a Effect of various treatments on total soluble protein (microgram/ml) of mung bean at 30 and 60 DAS during *Kharif* season 2022-23

4.2.7 Membrane Stability Index (%)

The effect of seed priming with gibberellin, SA (salicylic acid) or foliar application of zinc and boron on membrane stability index (%) was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of membrane stability index (%) was noted at 30, 60 DAS intervals (Table 4.2.7.1, 4.2.7.2 and Figure 4.2.7.1a and Figure 4.2.7.2a. In 2022 and 2023, the data was significant in the percentage of membrane stability index (%) by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that the maximum membrane stability index was found in T9 (91.32) followed by T10 (91.54) at 60 DAS. The minimum membrane stability index was found in control (T0) (77.75) which was significantly lower than priming with phytohormone and combined micronutrients foliar application and it was found at par with single phytohormones priming T1. The percentage of membrane stability index (%) was increased in T9 by 12.9% at 30-DAS and 14.9% at 60-DAS respectively as compared to the treatment T0 (control). It was also observed that percentage of membrane stability index (%) was lowest in (T2) i.e. 7.7% and 6.2% at 30 and 60 DAS respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. In *Summer* 2023, it was recorded that the maximum membrane stability index was found in T9 (88.60) followed by T10 (88.34) at 60 DAS. The minimum membrane stability index was found in control (T0) (74.29) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and it was found at par with single phytohormones priming T1. The percentage of membrane stability index (%) was significantly increased in treatment T9 (i.e. combined micronutrients (Zn+B) foliar application in gibberellin primed seed plants) 14.3% at 30-DAS and 16.2% at 60-DAS respectively as compared to treatment (T0). Similarly, it was found that the treatment T7 enhanced the percentage of membrane stability index (%) by 5.3% and 5.8% at 30 and 60 DAS when compared with treatment T3 (i.e. individual foliar application zinc). It was also observed that percentage of membrane stability index (%) was lowest in treatment (T1) (i.e. individual application of gibberellin primed seeds) i.e. 1.4% and 5.9% at 30 and 60 DAS respectively when compared with treatment (T6). The membrane stability index was slightly lower in *Summer* 2023 compared to *Summer* 2022. T10 consistently had the highest values in both years, though the percentage increase was generally higher in *Summer* 2023.

Table 4.2.7.1 Effect of various treatments on membrane stability index (MSI) in mung bean at 30 and 60 DAS during *Summer* season 2022 and 2023

	Membrane Stability Index (MSI) *Summer* 2022 and Summer 2023			
	30 DAS		60 DAS	
Treatments	**2022**	**2023**	**2022**	**2023**
T0	75.16[e]±2.67	72.64[d]±2.33	77.75[e]±0.85	74.29[e]±1.63
T1	77.91[de]±2.37	75.91[cd]±1.89	80.22[de]±1.30	76.82[de]±2.27
T2	78.2[cde]±3.13	76.2[cd]±3.15	82.59[cd]±3.68	79.3[cd]±3.91
T3	80.05[cde]±3.02	78.13[bcd]±3.88	82.98[cd]±1.36	79.7[cd]±0.57
T4	78.63[cde]±2.92	76.67[cd]±3.74	82.85[cd]±1.36	79.5[cd]±0.80
T5	82.23[bcd]±2.91	82.1[abc]±3.66	84.58[c]±1.29	84.42[b]±0.64
T6	81.79[bcd]±3.54	79.98[bc]±4.61	84.22[c]±1.22	81.34[bc]±2.10
T7	84.22[abc]±3.73	82.46[abc]±4.74	87.72[b]±1.25	84.58[b]±0.85
T8	83.81[abcd]±3.21	80.32[bc]±2.17	87.61[b]±0.55	83.64[b]±2.83
T9	86.29[ab]±3.17	84.72[abc]±4.34	91.32[a]±2.06	88.6[a]±1.99
T10	88.91[a]±3.79	87.47[a]±4.84	91.54[a]±1.15	88.34[a]±2.39
CD (at p≤ 0.05)	5.4	5.75	2.83	3.28
SEm (±)	1.82	1.94	0.95	1.11

In *Kharif* 2022 the percentage of membrane stability index (%) was significantly increased in treatment T10 (i.e. combined Zinc and boron (B) foliar application in salicylic acid primed seed plants) 16.2% at 30 DAS and 14.6% at 60 DAS respectively as compared to treatment (T0). Similarly, it was found that the treatment T5 enhanced the percentage of membrane stability index (%) by 4.8% and 7.4% at 30 and 60 DAS respectively when compared with treatment T1 (i.e. individual application of gibberellin primed seed plants). It was also observed that percentage of membrane stability index (%) was lowest in treatment (T4) i.e. 6.7% and 5.5% at 30, and 60 DAS respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023 it was recorded that the percentage of membrane stability index (%) was increased in T10 by 18% at 30-DAS and 15.4% at 60-DAS respectively as compared to the treatment (T0) control. It was also observed that percentage of membrane stability index (%)

was lowest in control (T3) i.e. 5.5% and 5.7% at 30 and 60 DAS respectively when compared with treatment (T5) i.e. foliar application of zinc in gibberellin primed seed plants. The control (T0) showed consistently lower membrane stability indices, with the percentage increase from treatments being more significant in *Kharif* 2023 compared to *Kharif* 2022. Both the *Summer* and *Kharif* season crop of mung bean membrane stability index (%) was slightly greater in *Summer* season as we compare to *Kharif* season, membrane stability index (%) in the crop of *Summer* season was higher. Priming seeds with SA, combined with foliar applications of zinc and boron, significantly enhances the membrane stability index (MSI) of mung bean leaves. This improvement in MSI indicates better protection and maintenance of cellular structures under stress conditions, which is crucial for plant growth and productivity **(Singh *et al.,* 2021; Kumar *et al.,* 2023; Song *et al.,* 2023**). Improved membrane stability helps maintain the physiological processes involved in pod and seed development, making them less susceptible to environmental stresses. This leads to enhanced pod formation, more efficient seed filling, and overall higher yield. A higher Membrane Stability Index (MSI) is often linked to increased antioxidant activity within the plant (**Verma *et al.,* 2020)**. Antioxidants like SOD, peroxide (POD) and catalase (CAT) protect cellular membranes from oxidative damage, thereby maintaining their stability. The integrated use of SA priming and foliar application of zinc and boron not only improves the physiological and biochemical health of mung bean plants but also translates into tangible benefits in terms of yield and quality. The similar results was found by **Zahrani *et al.,* 2021 Zaib *et al.,* 2024 and Rashid *et al.,* 2022.**

Table 4.2.7.2 Effect of various treatments on membrane stability index (MSI) in mung bean at 30 and 60 DAS during *Kharif* season 2022 and 2023

	Membrane Stability Index (MSI) *Kharif* 2022 and *Kharif* 2023			
	30 DAS		60 DAS	
Treatments	2022	2023	2022	2023
T0	73.32^{e}±2.87	72.42^{d}±2.47	76.24^{e}±0.83	74.96^{e}±1.58
T1	76.43^{de}±2.38	75.89^{cd}±2.01	78.58^{de}±1.28	77.43^{de}±2.19
T2	76.74^{cde}±3.14	76.2^{cd}±3.35	80.85^{cd}±3.48	81.83^{bc}±2.02
T3	78.57^{cde}±3.04	78.25^{bcd}±4.14	81.2^{cd}±1.30	80.24^{cd}±0.56
T4	77.16^{cde}±2.94	76.7^{cd}±3.98	81.04^{cd}±1.51	80.04^{cd}±0.79
T5	80.3^{bcd}±3.57	82.52^{abc}±3.94	84.82^{b}±2.99	84.83^{b}±0.60
T6	80.71^{bcd}±2.93	80.24^{bc}±4.93	82.71^{bc}±1.23	79.84^{cd}±3.79
T7	82.71^{abc}±3.76	82.92^{abc}±5.10	85.66^{b}±1.11	84.98^{b}±0.82
T8	82.32^{abcd}±3.23	80.61^{bc}±2.33	85.52^{b}±0.44	84.06^{b}±2.76
T9	84.82^{ab}±3.20	85.34^{abc}±4.67	89^{a}±1.98	88.88^{a}±1.92
T10	87.46^{a}±3.83	88.31^{a}±5.23	89.24^{a}±1.07	88.63^{a}±2.31
CD (at p≤ 0.05)	5.41	6.17	2.92	3.19
SEm (±)	1.82	2.08	0.98	1.07

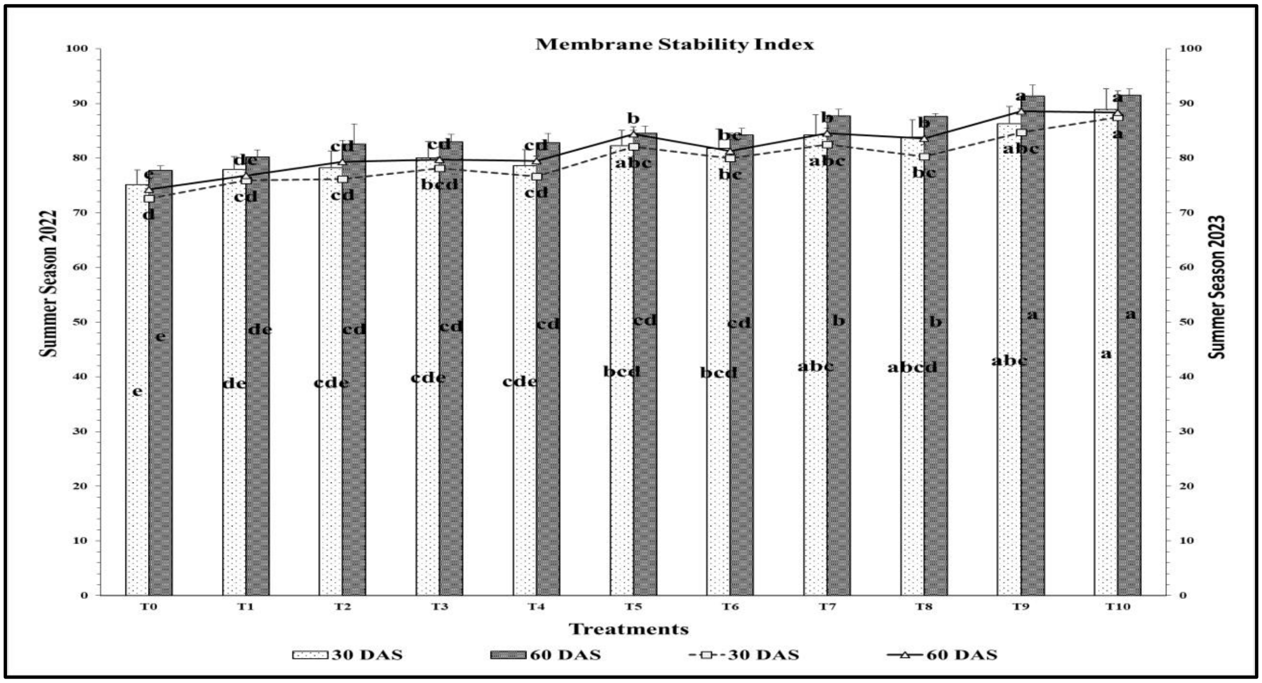


Figure 4.2.7.1a Effect of various treatments on membrane stability index (MSI) in mung bean at 30 and 60 DAS during *Summer* season 2022-23

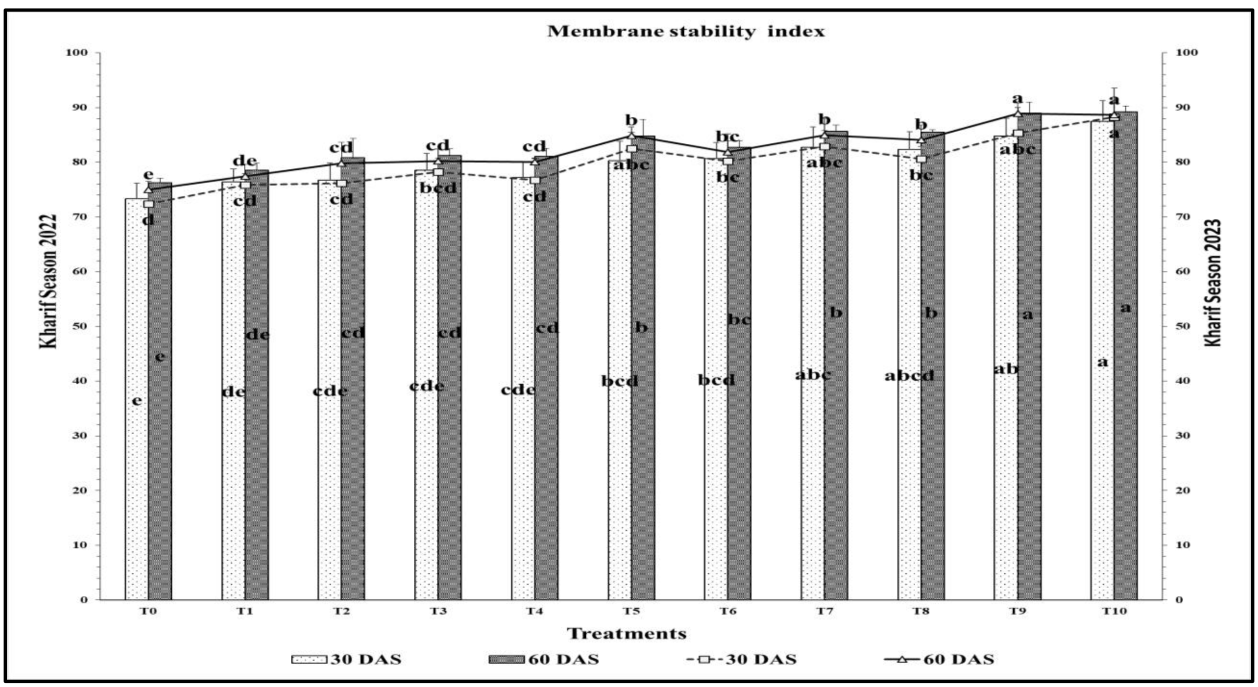


Figure 4.2.7.2a Effect of various treatments on membrane stability index (MSI) in mung bean at 30 and 60 DAS during *Kharif* season 2022-23

4.3. Yield Attributes

4.3.1 Number of seeds/pod

The influence of seed priming with gibberellin, salicylic acid, and foliar treatment of zinc and boron on the quantity of seeds per pod was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of number of seeds/pod was taken at harvest (Table 4.3.2.1 and 4.3.2.2, figure 4.3.2.1a, 4.3.2.2a). In 2022 and 2023, the percentages differed significantly number of seeds/pod by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that the maximum number of grains/pods was found in T9 (12) followed by T10 (12). The minimum number of grains/pods was found in control (T0) (10.33). The percentage of number of seeds/pod was increased in T9 by 13.9% as compared to the control T0. It was also observed that percentage of number of seeds/pod was lowest in control (T2) i.e. 3% respectively when compared with treatment (T7). In *Summer* 2023, it was recorded the highest of grains/pods was found in T9 (11.88) followed by T10 (11.55). The lowest of grains/pods was found in control (T0) (9.77). The percentage of number of seeds/pod was significantly increased in treatment (T9) 17.8% respectively as compared to control (T0). It was also observed that percentage of number of seeds/pod was lowest in treatment T1 (i.e. individual application of gibberellin primed seeds) i.e. 4.2% when compared with treatment (T6). The percentage of seeds per pod generally increased from *Summer* 2022 to *Summer* 2023, particularly for T9.

Table 4.3.1.1 Effect of various treatments on number of seeds/pod in mung bean during *Summer* season 2022 and 2023

Treatments	Number of seeds/pod *Summer* 2022	Number of seeds/pod *Summer* 2023
T0	10.33[b]±0.29	9.77[c]±0.20
T1	11[ab]±0.00	10[c]±0.34
T2	10.67[b]±0.58	10[c]±0.67
T3	11[ab]±0.00	10.22[c]±0.51
T4	11[ab]±1.00	10.11[c]±0.39
T5	11.33[ab]±0.58	10.55[bc]±0.84
T6	11[ab]±1.00	10.44[c]±0.84
T7	11[ab]±1.00	10.55[bc]±1.02
T8	11[ab]±0.00	10.33[c]±0.00
T9	12[a]±0.00	11.88[a]±0.69
T10	12[a]±0.00	11.55[ab]±0.19
CD	0.84	0.99
SE(m)	0.34	0.33

In *Kharif* 2022 the percentage of number of seeds/pod was significantly increased in treatment T10 (i.e. combined Zinc and boron foliar application in salicylic acid primed seed plants) 16.1% respectively as compared to control (T0). It was also observed that percentage of number of seeds/pod was lowest in treatment (T4) i.e. 3.2% when compared with treatment (T8). In *Kharif* 2023 it was recorded that the percentage of pods/plant was increased in T10 by 3% respectively as compared to the control T0. It was also observed that percentage of number of seeds/pod was lowest in control (T3) i.e. 3.5% when compared with treatment (T5). The percentage of seeds per pod increased for T10 and other treatments in *Kharif* 2022, but the percentage increases were lower in *Kharif* 2023. The maximum number of grains/pods showed significant increases in both years. Both the *Summer* and *Kharif* season crop of mung bean number of seeds/pod was slightly greater in *Summer* season as we compare to *Kharif* season, number of seeds/pod in the crop of *Summer* season was higher. Number of seeds/pod of crop growing in 2022 year performs well as compare to crop grows in 2023 seasons. The integrated approach of applying zinc and boron as a foliar spray helps mung bean plants optimize their reproductive potential. The number of seeds per pod has a direct impact on the overall yield; more seeds per pod generally result in a higher seed count per plant, thereby boosting total yield. Gibberellic acid (GA) can promote flower development and fertility, improving pollination and seed set, which in turn increases the number of seeds per pod. The findings are consistent with **Mubeen *et al.*, 2020, Than *et al.*, 2022, and Yarnia *et al.*, 2024**. Foliar zinc application enhances health and functionality of reproductive organs, leading to better fertilization rates and more seeds per pod. Boron application also enhances pollen viability and fertilization efficiency, resulting in a higher number of seeds per pod. By combining GA priming with foliar applications of Zn and B, mung bean enhanced overall yield due to the higher seed count per pod and potentially improved seed quality. The results are in accordance with those of **Ishfaq *et al.*, 2022; Kumar *et al.*, 2023; Selim *et al.*, 2023;** and **Kayata *et al.*, 2024.**

Table 4.3.1.2 Effect of various treatments on number of seeds/pod in mung bean during *Kharif* season 2022 and 2023

Treatments	Number of seeds\pod *Kharif* 2022	Number of seeds/pod *Kharif* 2023
T0	$9.23^{d}\pm0.40$	$8.57^{c}\pm0.28$
T1	$9.9^{bcd}\pm0.10$	$8.8^{c}\pm0.47$
T2	$9.57^{cd}\pm0.49$	$8.8^{c}\pm0.87$
T3	$9.9^{bcd}\pm0.10$	$9.02^{c}\pm0.66$
T4	$9.9^{bcd}\pm0.36$	$8.91^{c}\pm0.24$
T5	$10.57^{ab}\pm0.72$	$9.35^{bc}\pm0.94$
T6	$10.23^{abc}\pm0.78$	$9.24^{bc}\pm0.97$
T7	$10.23^{abc}\pm0.87$	$9.35^{bc}\pm1.16$
T8	$10.23^{abc}\pm0.15$	$9.13^{bc}\pm0.20$
T9	$11^{a}\pm0.00$	$10.68^{a}\pm0.70$
T10	$11^{a}\pm0.00$	$10.35^{ab}\pm0.28$
CD	0.84	0.98
SE(m)	0.28	0.33

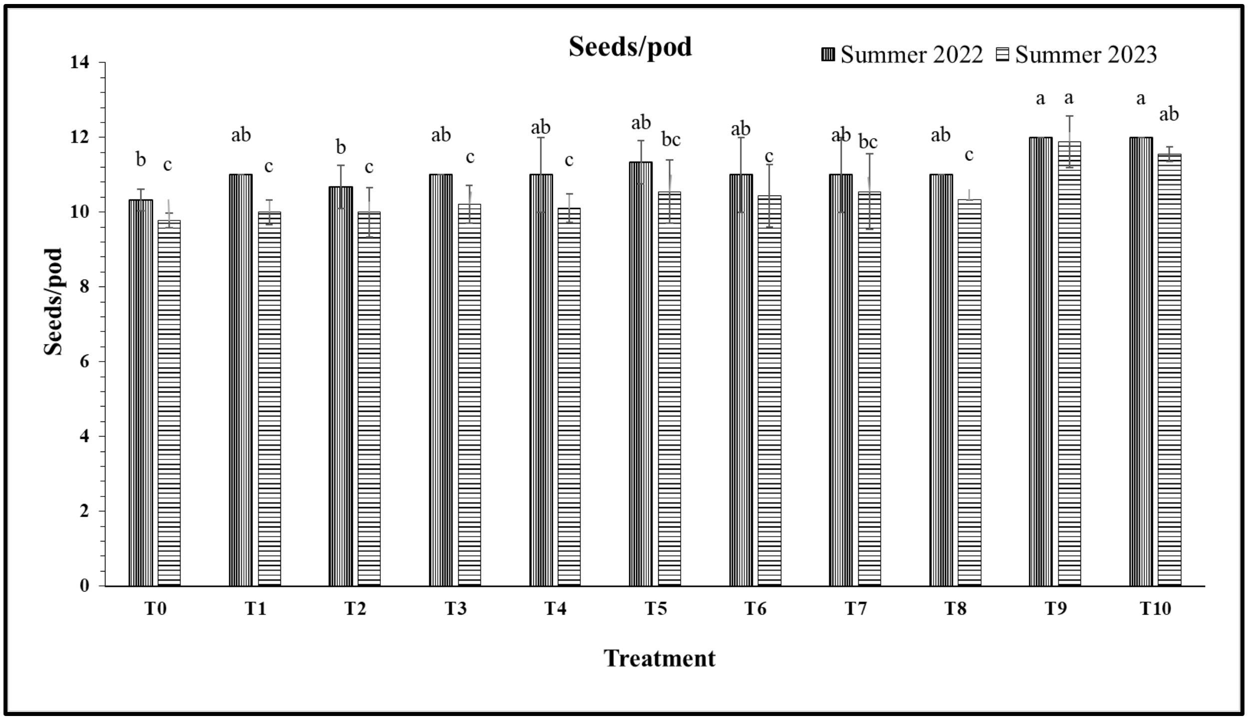


Figure 4.3.1.1a Effect of various treatments on number of seeds/pod in mung bean during *Summer* season 2022 and 2023

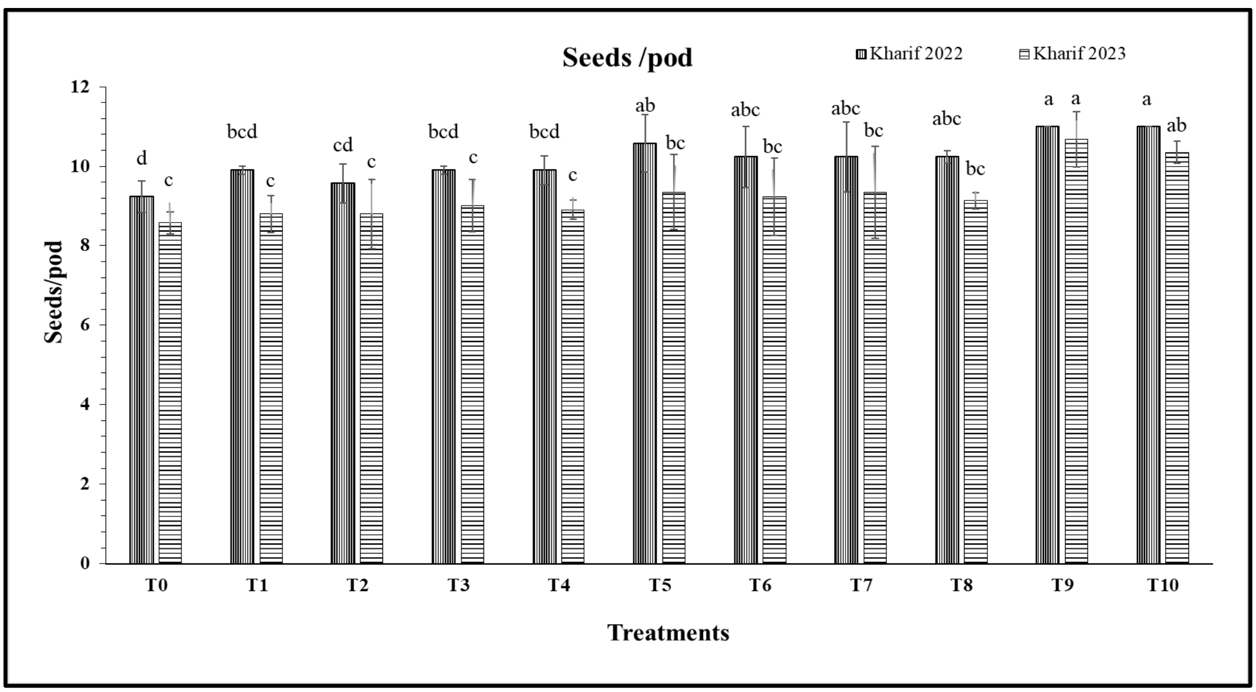


Figure 4.3.1.2a Effect of various treatments on number of seeds/pod in mung bean during *Kharif* season 2022 and 2023

4.3.2. Number of pods/plant

The effect of seed priming with gibberellin, salicylic acid and foliar application of zinc and boron on number of pods/plant zinc along with boron foliar treatment affects the quantity of pods per plant was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The number of pods/plants was counted throughout harvest. (Table 4.3.2.1, 4.3.2.2, figure 4.3.2.1a, 4.3.2.2a). In 2022 and 2023, there was a significant difference in the % of number of pods/plant by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was found that the highest number of pods per plant was determined in T9 (43.33) followed by T10 (42.33) and number of pods/plant of treatment T9 was significantly maximum as compared with all other treatments and it was found at par with T10 treatment. The minimum number of pods/plant was found in control (T0) (32.33) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and it was found at par with single phytohormones priming i.e. T1 (33.67) and T2 (33). The percentage of number of pods/plant was increased in T9 by 25.4% as compared to the treatment T0. It was also observed that percentage of number of pods/plant was lowest in control (T2) i.e. 17.5% respectively when compared with treatment (T7). Similarly, it was found that the treatment T6 enhanced the percentage of number of pods/plant by 10.1% when compared with treatment T4. In *Summer* 2023, it was recorded that the highest pods/plant was found in T9 (40.57) followed by T10 (39.23) and number of pods/plant of treatment T9 was significantly maximum as compared with all other treatments and it was found at par with treatment T10. The minimum pods/plant was found in control (T0) (29.37) which was significantly lower than priming with phytohormone and combined foliar application of zinc and boron and it was found at par with single phytohormones priming i.e. T1 (31.37) and T2 (30.70). The percentage of number of pods/plant was significantly increased in treatment (T9) 27.6% respectively as compared to control (T0). Similarly, it was found that the treatment T7 enhanced the percentage of number of pods/plant by 5.2% when compared with treatment T3. It was also observed that percentage of pods/plant was lowest in treatment T1 i.e. 13.6% when compared with treatment (T6). Both years showed T9 and T10 as the top-performing treatments for the maximum number of pods per plant. However, the actual number of pods per plant slightly decreased in 2023 compared to 2022.

Table 4.3.2.1 Effect of various treatments on pods/plant in mung bean during *Summer* season 2022 and 2023

Treatments	Pods/plant *Summer* 2022	Pods/plant *Summer* 2023
T0	32.33^{e}±3.21	29.37^{e}±2.15
T1	33.67^{cd}±2.52	31.37^{de}±2.58
T2	33^{cd}±2.00	30.7^{de}±1.90
T3	37.33^{bc}±2.52	35.03^{bcd}±2.58
T4	35.67^{bcd}±3.51	33.37^{cde}±3.56
T5	40.33^{ab}±2.08	37.3^{abc}±1.37
T6	39.67^{ab}±3.06	36.3^{abc}±2.98
T7	40^{ab}±2.00	36.97^{abc}±2.22
T8	39.67^{ab}±2.52	36.3^{abc}±2.59
T9	43.33^{a}±2.08	40.57^{a}±2.02
T10	42.33^{a}±2.08	39.23^{ab}±2.25
CD	3.66	3.61
SE(m)	1.23	1.22

In *Kharif* 2022 the percentage of number of pods/plant was significantly increased in treatment T10 (i.e. combined foliar application of Zinc and boron in salicylic acid primed seed plants) 25.2% respectively as compared to control (T0). Similarly, it was found that the treatment T5 enhanced the percentage of number of pods/plant by 17.6% when compared with treatment T1. It was also found that percentage of pods/plant was lowest in treatment (T4) i.e. 11% when compared with treatment (T8). In *Kharif* 2023 it was recorded that the percentage of pods/plant was increased in T10 by 3% respectively as compared to the control T0. It was also recorded that percentage of number of pods/plant was lowest in control (T3) i.e. 3.5% when compared with treatment (T5). Similarly, it was found that the treatment T8 enhanced the percentage of number of pods/plant by 11.5% when compared with treatment T2. In *Kharif* 2022, the treatment T10 showed a significant increase in the number of pods per plant by 25.2% compared to the control (T0), whereas in *Kharif* 2023, the increase for T10 was only 3%, indicating a decrease in the treatment's effectiveness. Both the *Summer* and *Kharif* season crop of mung bean number of pods/plant was slightly greater in *Summer* season as we compare to *Kharif* season, number of pods/plant in the crop of *Summer* season was higher. As we compare both the 2022 and 2023 year crops, number of pods/plant of crop growing in 2022 year performs well as compare to crop grows in 2023 seasons. Priming with GA and micronutrient foliar application together, create a synergistic effect that maximizes the reproductive potential and yield of mung bean plants.GA priming can lead to an increase in the number of flowers and their successful development into pods, thus increasing the number of pods per plant. These findings are in accordance with **Aslam *et al.,* 2021; Rafique *et al.,* 2022; Azimi *et al.,* 2022; Iqbal *et al.,* 2023.** Foliar application of **Zinc** is vital for enzyme activation, protein synthesis, and growth regulation. It plays a role in pollen formation, fertilization, and fruit set. The application of boron improves the reproductive success of plants, enhancing the formation and retention of flowers and pods. (**Banerjee *et al.,* 2022).** Boron is crucial for pollen germination, pollen tube growth, and fruit set. The number of pods per plant is directly related to yield. More pods generally mean more seeds. Improved plant height, biomass, leaf area, and root development due to GA, Zn, and B treatments support better pod formation and overall plant health. Similar finding were obtained by **Chen *et al.,* 2020; Mubeen *et al.,* 2020; Than *et al.,* 2022; Selim *et al.,* 2023.**

Table 4.3.2.2 Effect of various treatments on pods/plant in mung bean during *Kharif* season 2022 and 2023

Treatments	Pods/plant *Kharif* 2022	Pods/plant *Kharif* 2023
T0	$30.73^{e}\pm3.03$	$27.93^{d}\pm1.99$
T1	$32.07^{de}\pm2.60$	$29.93^{cd}\pm2.35$
T2	$31.4^{de}\pm2.11$	$29.27^{cd}\pm2.20$
T3	$35.73^{bcd}\pm2.32$	$33.6^{abc}\pm2.45$
T4	$34.07^{cde}\pm3.31$	$31.93^{bcd}\pm3.48$
T5	$38.93^{ab}\pm2.24$	$34.83^{abc}\pm1.19$
T6	$38.27^{abc}\pm2.83$	$33.83^{abc}\pm3.84$
T7	$38.6^{abc}\pm1.75$	$34.5^{abc}\pm3.94$
T8	$38.27^{abc}\pm2.51$	$33.83^{abc}\pm4.29$
T9	$42.1^{a}\pm2.09$	$38.57^{a}\pm3.23$
T10	$41.1^{a}\pm1.78$	$37.23^{ab}\pm2.67$
CD	3.67	4.26
SE(m)	1.24	1.43

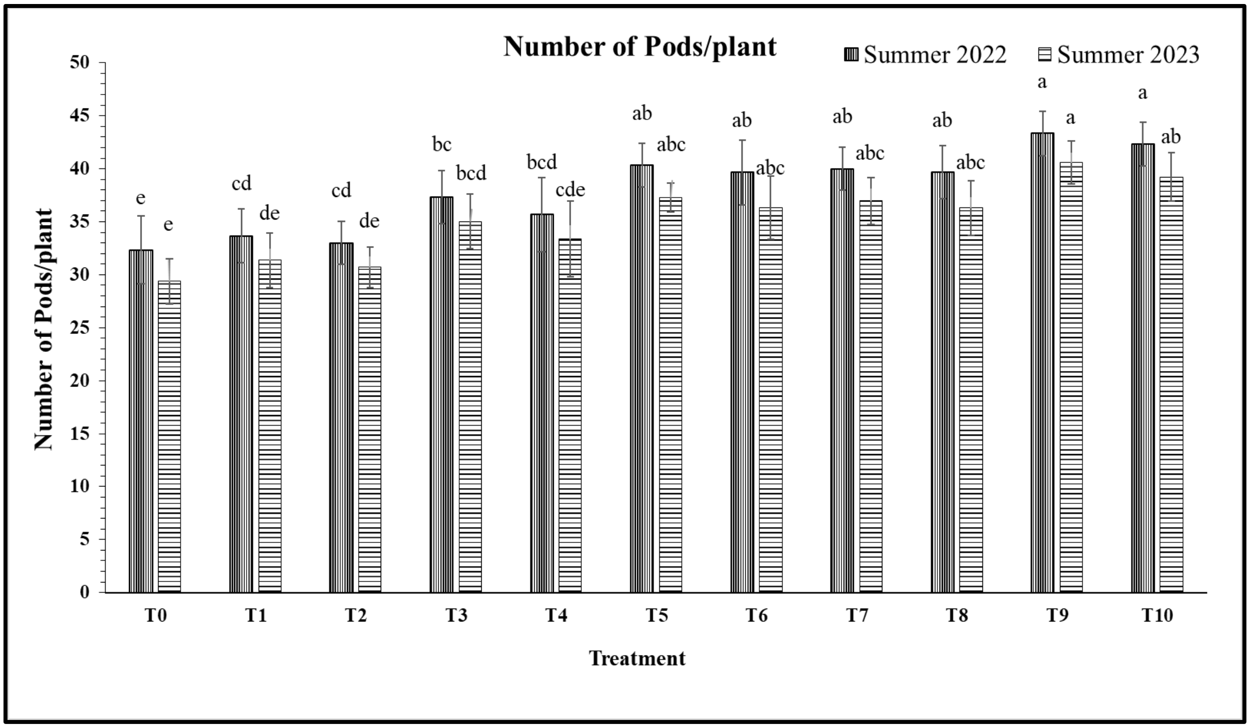


Figure 4.3.2.1a Effect of various treatments on pods/plant in mung bean during *Summer* season 2022 and 2023

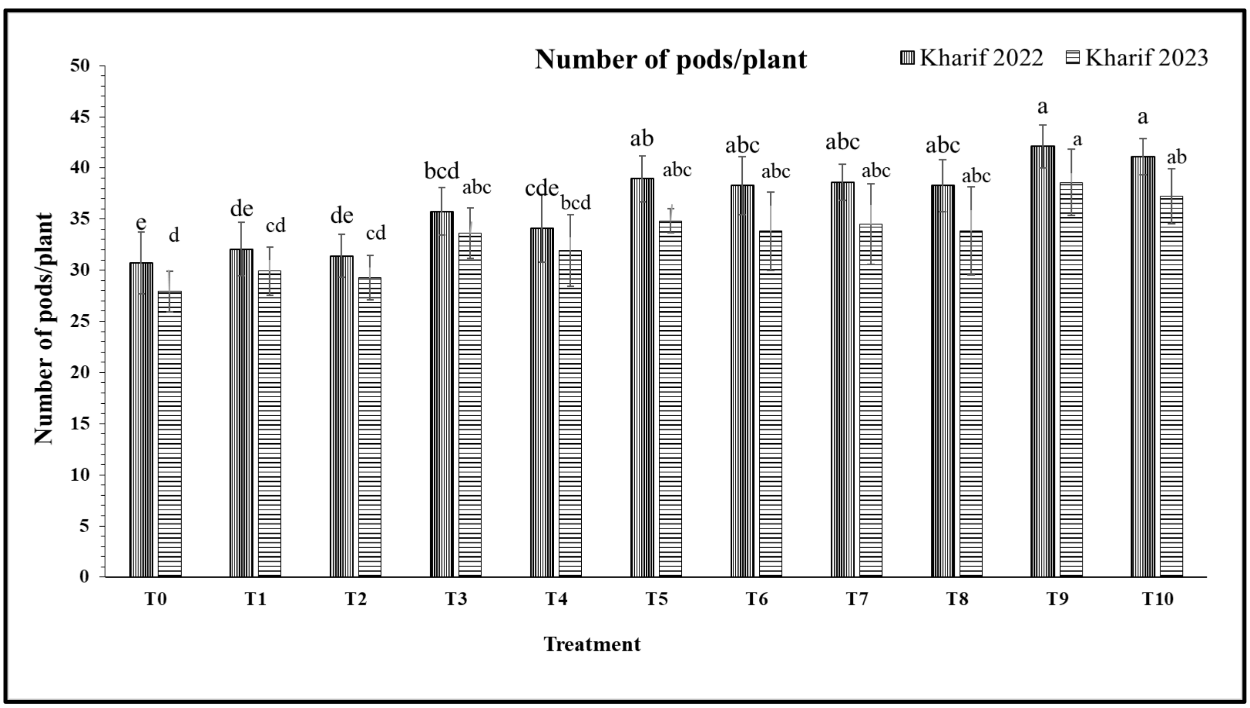


Figure 4.3.2.2a Effect of various treatments on pods/plant in mung bean during *Kharif* season 2022 and 2023

4.3.3 Pod Length (cm)

The effect of seed priming with gibberellin, salicylic acid along with foliar application of zinc and boron on pod length was observed in *Summer* and *Kharif* season in mung bean plant during 2022-23. The data of pod length was taken at harvest (Table 4.3.3.1, 4.3.3.2, figure 4.3.3.1a, 4.3.3.2a). In 2022 and 2023, In *Summer* 2022, it was recorded that the maximum pod length was found in T9 (9.67 cm) followed by T10 (8.50 cm). The minimum pod length was found in control (T0) (7.50 cm). The percentage of pod length was increased in T9 by 22.4% as compared to the control T0. It was also observed that percentage of pod length was lowest in control (T2) i.e. 7.9% respectively when compared with treatment (T7). In *Summer* 2023 the percentage of pod length was significantly increased in treatment T9 23.4% respectively as compared to control (T0). Similarly, it was found that the treatment T7 enhanced the percentage of number pod length by 2.9% when compared with treatment T3. The percentage increase in pod length for T9 slightly improved from 22.4% in 2022 to 23.4% in 2023, while the other treatments showed varying levels of effectiveness.

Table 4.3.3.1 Effect of various treatments on pod length (cm) in mung bean during *Summer* season 2022 and 2023

Treatments	Pod length *Summer* 2022	Pod length *Summer* 2023
T0	$7.50^{c}\pm0.87$	$7.10^{c}\pm0.00$
T1	$7.83^{bc}\pm0.58$	$7.43^{bc}\pm0.58$
T2	$7.67^{bc}\pm0.29$	$7.27^{bc}\pm0.29$
T3	$8.33^{bc}\pm0.58$	$7.70^{bc}\pm0.58$
T4	$8.00^{bc}\pm0.50$	$7.60^{bc}\pm0.50$
T5	$8.47^{b}\pm0.06$	$8.07^{b}\pm0.55$
T6	$8.17^{bc}\pm0.29$	$7.83^{bc}\pm0.29$
T7	$8.33^{bc}\pm0.29$	$7.93^{bc}\pm0.29$
T8	$8.17^{bc}\pm0.29$	$7.77^{bc}\pm0.76$
T9	$9.67^{a}\pm0.29$	$9.27^{a}\pm0.21$
T10	$8.50^{b}\pm0.50$	$8.13^{b}\pm0.45$
CD	0.77	0.66
SE(m)	0.26	0.23

In *Kharif* 2022 the percentage of pod length was significantly increased in treatment T10 (i.e. combined Zinc and boron (B) foliar application in salicylic acid primed seed plants) 15.3% respectively as compared to control (T0). Similarly, it was found that the treatment T5 enhanced the percentage of pod length by 9.3% when compared with treatment T1 (i.e. individual application of gibberellin primed seed plants). It was also observed that percentage of pod length was lowest in treatment (T4) i.e. 3.8% when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants. In *Kharif* 2023 it was recorded that the maximum pod length was found in T9 (8.90 cm) followed by T10 (7.73 cm). The minimum pod length was found in control (T0) (6.53 cm). The percentage of pod length was increased in T10 by 15.5% respectively as compared to the control T0. It was also observed that percentage of pod length was lowest in control (T3) i.e. 3.4% when compared with treatment (T5) i.e. foliar application of zinc in gibberellin primed seed plants. The pod length of mung bean crops was slightly greater in the *Summer* season compared to the *Kharif* season, with *Summer* crops showing longer pods. Gibberellic acid promotes cell division and elongation in the pods, contributing to their increased length. Foliar application of boron (B) enhances flower formation and fruit set, which improves pod development. There is a direct correlation between pod length and yield in mung beans, as longer pods generally contain more seeds per pod, leading to higher yields **(Deol 2018; Nourin 2021; Kumar 2021**). Improved leaf area and higher chlorophyll content due to Zn application boost photosynthetic efficiency, supplying more energy for pod development. Healthy leaves support sustained growth and contribute to longer pods. Similar findings were found by **Haider *et al.*, 2020; Banerjee *et al.*, 2022 and Krishna *et al.*, 2022.**

Table 4.3.3.2 Effect of various treatments on pod length (cm) in mung bean during *Kharif* season 2022 and 2023

Treatments	Pod length *Kharif* 2022	Pod length *Kharif* 2023
T0	7.03^{d}±1.01	6.53^{c}±1.10
T1	7.37^{bcd}±0.57	6.87^{ab}±0.60
T2	7.2^{cd}±0.30	6.7^{ab}±0.36
T3	7.87^{bcd}±0.57	7.37^{ab}±0.60
T4	7.53^{bcd}±0.57	7.03^{ab}±0.64
T5	8.13^{bc}±0.45	7.63^{ab}±0.49
T6	7.83^{bcd}±0.25	7.33^{ab}±0.12
T7	8^{bcd}±0.17	7.5^{ab}±0.17
T8	7.83^{bcd}±0.68	7.33^{ab}±0.51
T9	9.47^{a}±0.38	8.9^{a}±0.40
T10	8.3^{b}±0.46	7.73^{b}±0.70
CD	0.91	0.88
SE(m)	0.31	0.30

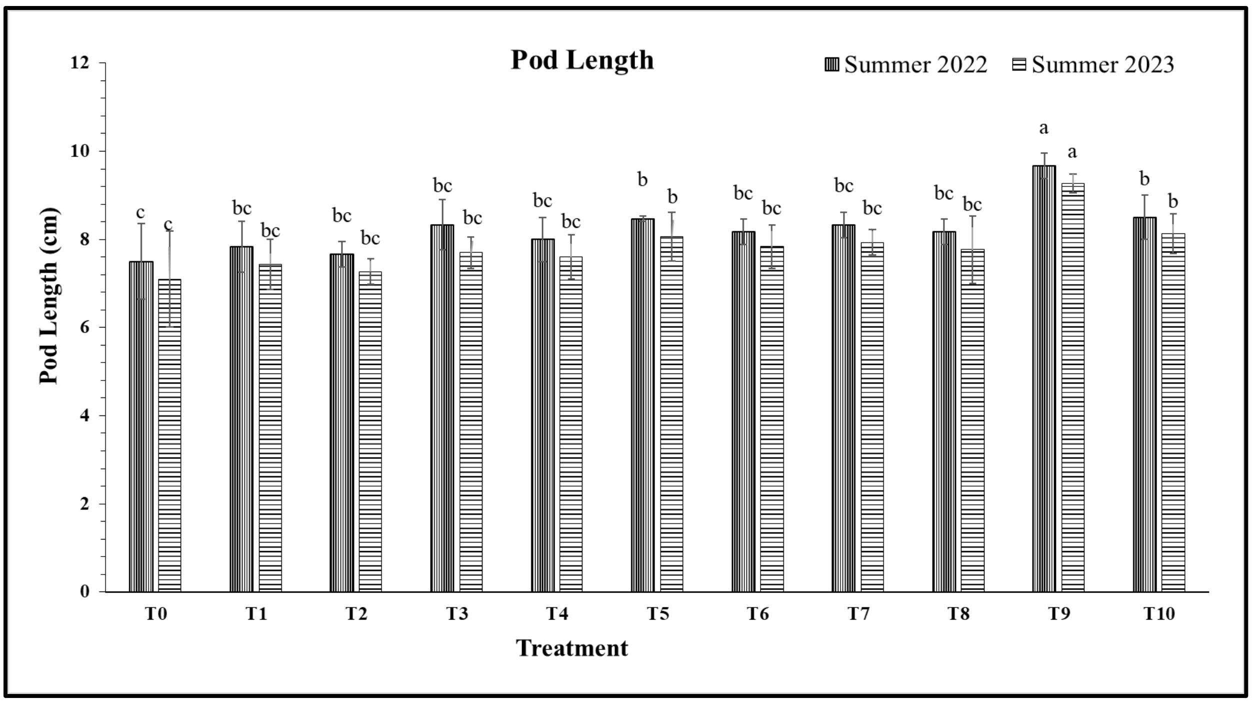


Figure 4.3.3.1a Effect of various treatments on pod length (cm) in mung bean during *Summer* season 2022 and 2023

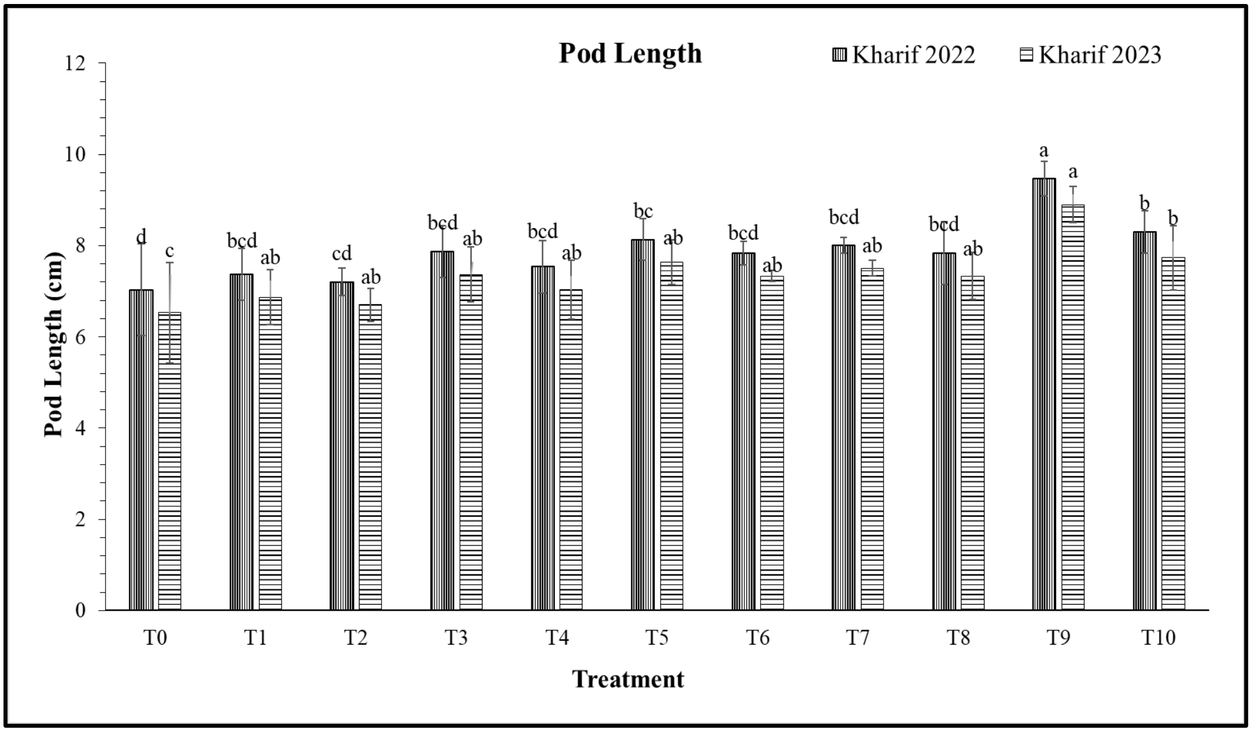


Figure 4.3.3.2a Effect of various treatments on pod length (cm) in mung bean during *Kharif* season 2022 and 2023

4.3.4 1000 Seed weight (g)

The impact of seed priming with gibberellin and salicylic acid foliar application of zinc and boron on 1000 seed weight (g) was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of 1000 seed weight (g) was taken at harvest (Table 4.3.4.1, 4.3.4.2, figure 4.3.4.1a, 4.3.4.2a). In 2022 and 2023, the percentages were significantly different of 1000 seed weight (g) by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that the maximum test weight was found in T9 (46.9 g) followed by T10 (46.30 g). The minimum 1000 seed weight was found in control (T0) (42 g). The percentage of 1000 seed weight (g) was increased in T9 by 10.4% as compared to the treatment (T0) control. It was also observed that percentage of 1000 seed weight (g) was lowest in control (T2) i.e. 6.6% respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants, In *Summer* 2023 the percentage of 1000 seed weight (g) was significantly increased in treatment T9 (i.e. combined foliar application of Zinc and boron in gibberellin primed seed plants) 10.6% respectively as compared to control (T0). It was also found that percentage of 1000 seed weight (g) was lowest in treatment T1 (i.e. individual application of gibberellin primed seeds) i.e.

4.2% when compared with treatment (T6). In both *Summer* 2022-2023 years, T9 showed a significant increase in 1000 seed weight.

Table 4.3.4.1 Effect of various treatments on 1000 seed weight (g) of mung bean during *Summer* season 2022 and 2023

Treatments	1000 Seed weight *Summer* 2022	1000 Seed weight *Summer* 2023
T0	42.00^{d}±0.70	41.3^{e}±0.80
T1	42.76^{cd}±1.63	42.07^{de}±1.92
T2	42.30^{cd}±0.70	41.6^{e}±0.40
T3	43.43^{bcd}±0.86	42.73^{cde}±1.16
T4	43.10^{bcd}±1.31	42.40^{cde}±1.31
T5	45.66^{abc}±1.88	44.97^{abc}±1.05
T6	44.63^{abcd}±3.09	43.93^{abcde}±1.60
T7	45.36^{abcd}±1.80	44.67^{abcd}±1.96
T8	44.10^{abcd}±1.45	43.40^{bcde}±1.64
T9	46.90^{a}±2.15	46.20^{a}±1.31
T10	46.33^{ab}±2.30	45.63^{ab}±1.21
CD	2.15	2.03
SE(m)	0.96	0.68

In *Kharif* 2022 the percentage of 1000 seed weight (g) was significantly increased in treatment T10 9.6% respectively as compared to control (T0). Similarly, it was found that the treatment T5 enhanced the percentage of 1000 seed weight (g) by 7.5% when compared with treatment T1. The proportion of 1000 seed weight (g) was also found to be lowest in treatment (T4) i.e. 2.4% when compared with treatment (T8). In *Kharif* 2023 it was recorded that the maximum 1000 seed weight was found in T9 (43.59 g) followed by T10 (43.58 g). The minimum test weight was found in control (T0) (39 g). The percentage of 1000 seed weight (g) was increased in T10 by 10.5% respectively as compared to the control T0. It was also observed that percentage of 1000 seed weigh (g) was lowest in control (T3) i.e. 4.7% when compared with treatment (T5). Similarly, it was found that the treatment T8 enhanced the percentage of 1000 seed weight (g) by 4.5% when compared with treatment T2. In both 2022-2023 *Kharif* seasons, treatments involving combined foliar applications (T9 and T10) consistently showed the highest increases in 1000 seed weight.

Both the *Summer* and *Kharif* season crop of mung bean 1000 seed weight (g) was slightly greater in *Summer* season as we compare to *Kharif* season, 1000 seed weight (g) in the crop of *Summer* season was higher. GA priming, combined with foliar applications of Zn and B, plays a significant role in enhancing the 1000 seed weight of mung bean seeds. These treatments promote robust plant growth, efficient nutrient utilization, and optimal seed development, all contributing to higher test weight. The positive effects of these treatments on morphological parameters like plant height, biomass, leaf area, chlorophyll content, root development, and flower and pod setting collectively enhance yield and seed quality in mung bean cultivation (**Hussain *et al.,* 2021)**. By optimizing these factors, farmers can achieve higher yields and superior seed quality. Test weight is directly related to yield; higher test weight indicates better seed quality and more productive plants. Taller plants with more biomass have a greater capacity for photosynthesis and nutrient assimilation, supporting heavier seeds. Foliar application of boron also improves the translocation of sugars and nutrients to developing seeds, contributing to higher test weight. The result are accordance with those of **Kavya *et al.,* 2021; Bhadru *et al.,* 2019; Selim *et al.,* 2023; Verma *et al.,* 2020; Krishna *et al.,* 2022.**

Table 4.3.4.2 Effect of various treatments on 1000 seed weight (g) of mung bean during *Kharif* season 2022 and 2023

Treatments	1000 Seed weight *Kharif* 2022	1000 Seed weight *Kharif* 2023
T0	40.03^{d}±0.91	39^{d}±1.05
T1	40.33^{d}±1.23	39.3^{d}±1.40
T2	40.17^{d}±0.96	39.13^{d}±1.30
T3	41.6^{bcd}±1.51	40.56^{bcd}±0.78
T4	41.00^{cd}±1.20	39.97^{cd}±0.95
T5	43.60^{ab}±1.34	42.57^{ab}±1.58
T6	42.04^{bcd}±1.04	41.01^{bcd}±0.98
T7	43.00^{abc}±1.10	41.97^{abc}±1.27
T8	42.00^{bcd}±1.61	40.97^{bcd}±1.70
T9	44.62^{a}±0.72	43.59^{a}±0.70
T10	44.28^{a}±1.36	43.58^{a}±1.00
CD	1.95	1.88
SE(m)	0.66	0.63

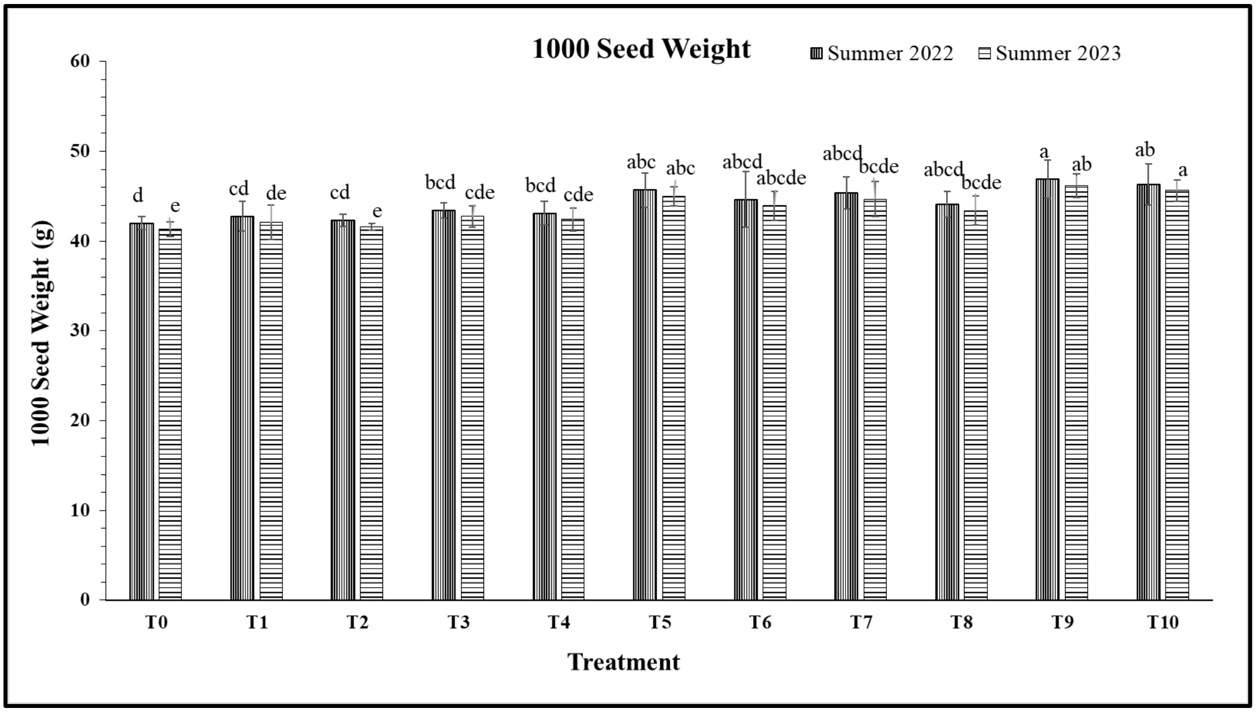


Figure 4.3.4.1a Effect of various treatments on 1000 seed weight (g) of mung bean during *Summer* season 2022 and 2023

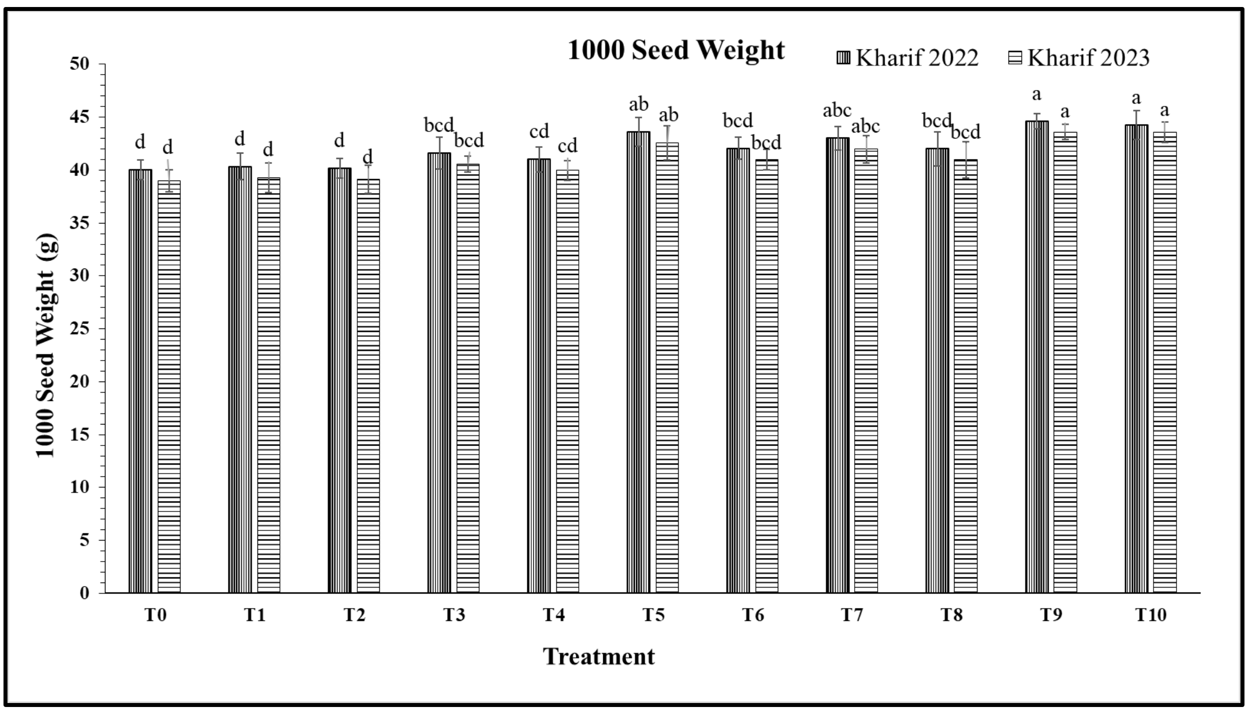


Figure 4.3.4.2a Effect of various treatments on 1000 seed weight (g) of mung bean during *Kharif* season 2022 and 2023

4.3.5 Seed Yield (q/ha)

The impact of seed priming with gibberellin, SA (salicylic acid) or foliar treatment of zinc and boron on seed yield (q/ha) was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of seed yield (q/ha) was taken at harvest (Table 4.3.5.1, 4.3.5.2, figure 4.3.5.1a, 4.3.5.2a). In 2022 and 2023, there was a significant difference in the percentage of seed yield (q/ha) by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that the maximum seed yield was found in T9 (13.50 q/ha) followed by (T10) (13.26 q/ha). The minimum seed yield was found in control (T0) (10.02 q/ha). The percentage of seed yield (q/ha) was increased in T9 by 34.7% as compared to the treatment T0 (control). It was also observed that percentage of seed yield (q/ha) was lowest in control (T2) i.e. 15.6% respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. Similarly, it was found that the treatment T6 (i.e. foliar application of boron in Gibberellin primed seed plants) enhanced the percentage of seed yield (q/ha) by 11.6% when compared with treatment T4 i.e. individual foliar application of boron. In *Summer* 2023, it was recorded that the maximum seed yield was found in T9 (12.75 q/ha) followed by (T10) (12.51 q/ha). The minimum seed yield was found in control (T0) (9.47 q/ha). The percentage of seed yield (q/ha) was significantly increased in treatment T9 (i.e. combined foliar application of Zinc and boron in gibberellin primed seed plants) 34.9% respectively as compared to control (T0). Similarly, it was found that the treatment T7 enhanced the percentage of number seed yield (q/ha) by 11.5% when compared with treatment T3 (i.e. individual foliar application zinc). It was also observed that percentage of seed yield (q/ha) was lowest in treatment T1 (i.e. individual application of gibberellin primed seeds) i.e. 12.6% when compared with treatment (T6). In both *Summer* 2022-2023 years, T9 had the highest seed yield, but there was a slight decrease in yield from 13.50 q/ha in 2022 to 12.75 q/ha in 2023. However, the percentage increase relative to the control remained high, slightly increasing from 34.7% in 2022 to 34.9% in 2023.

Table 4.3.5.1 Effect of various treatments on seed yield (q/ha) in mung bean during *Summer* season and 2023

Treatments	Seed yield (q/ha) *Summer* 2022	Seed yield (q/ha) *Summer* 2023
T0	10.02^{g}±0.18	9.47^{g}±0.21
T1	10.43^{fg}±0.25	9.88^{fg}±0.29
T2	10.34^{fg}±0.34	9.79^{fg}±0.27
T3	10.94^{ef}±0.37	10.39^{ef}±0.36
T4	10.56^{fg}±0.45	10.01^{fg}±0.43
T5	12.57^{b}±0.48	11.90^{b}±0.43
T6	11.78^{cd}±0.39	11.12^{cd}±0.29
T7	12.25^{bc}±0.46	11.59^{bc}±0.37
T8	11.45^{de}±0.49	10.85^{de}±0.36
T9	13.50^{a}±0.40	12.75^{a}±0.21
T10	13.26^{a}±0.43	12.51^{a}±0.36
CD	0.63	0.55
SE(m)	0.21	0.19

In *Kharif* 2022 the percentage of seed yield (q/ha) was significantly increased in treatment T10 i.e. 31.5% respectively as compared to control (T0). Similarly, it was found that the treatment T5 enhanced the percentage of seed yield (q/ha) by 20.3% when compared with treatment T1. It was also observed that percentage of seed yield (q/ha) was lowest in treatment (T4) i.e. 7.8% when compared with treatment (T8). In *Kharif* 2023 it was recorded that the percentage of seed yield (q/ha) was increased in T10 by 31.5% respectively as compared to the treatment T0 (control). It was also observed that percentage of seed yield (q/ha) was lowest in control (T3) i.e. 14.9% when compared with treatment (T5). Similarly, it was found that the treatment T8 enhanced the percentage of seed yield (q/ha) by 6% when compared with treatment T2. T10 showed consistent performance with a 31.5% increase in both *Kharif* sesons of 2022-2023 years. The yield impact of T5 was significantly higher in *Kharif* 2022 (20.3%) compared to T8's 6% increase in *Kharif* 2023. Both the *Summer* and *Kharif* season crop of mung bean seed yield (q/ha) was slightly greater in *Summer* season as we compare to *Kharif* season, seed yield (q/ha) in the crop of *Summer* season was higher. As we compare both the 2022 and 2023 year crops, seed yield (q/ha) of crop growing in 2022 year performs well as compare to crop grows in 2023 seasons. In mung bean phytohormone priming in seeds with Zinc and boron (B) foliar application improves yield quantity, factors like seed size, uniformity, and nutrient content also contribute to overall seed quality. Foliar application of zinc and boron in mung bean cultivation can lead to increased yield by promoting better plant growth or uptake of nutrients **(Dhaliwal *et al.*, 2021; Sayed *et al.*, 2024).** Taller plants with a well-developed canopy often capture more sunlight, leading to increased photosynthesis and higher yields. Application of GA_3 improves the higher number of pods generally correlates with increased yield, as each pod represents potential seeds. The outcomes are in close agreement with **López *et al.*, 2020; Przybylska *et al.*, 2021; Sayed *et al.*, 2024).** The current study showed that micronutrient intake significantly increased with external supplementation. This trend can be attributed to the combined effects of improved yield and higher nutrient concentration. Additionally, supplying nutrients through various fertilizers led to greater nutritional availability compared to the control group. The results are consistent with those of **Jamal *et al.* (2018), Quddus *et al.* (2020), and Nourin (2021); Sujith *et al.* (2022).**

Table 4.3.5.2 Effect of various treatments on seed yield (q/ha) in mung bean during *Kharif* season 2022 and 2023

Treatments	Seed yield (q/ha) *Kharif* 2022	Seed yield (q/ha) *Kharif* 2023
T0	$9.75^{g}\pm0.16$	$9.27^{h}\pm0.17$
T1	$10.16^{fg}\pm0.26$	$9.68^{gh}\pm0.25$
T2	$10.07^{fg}\pm0.29$	$9.59^{gh}\pm0.28$
T3	$10.64^{ef}\pm0.35$	$10.16^{fg}\pm0.34$
T4	$10.29^{fg}\pm0.48$	$9.81^{gh}\pm0.47$
T5	$12.22^{b}\pm0.34$	$11.67^{bc}\pm0.35$
T6	$11.43^{cd}\pm0.36$	$10.89^{de}\pm0.34$
T7	$11.90^{bc}\pm0.36$	$11.36^{cd}\pm0.35$
T8	$11.09^{de}\pm0.51$	$10.55^{ef}\pm0.50$
T9	$13.05^{a}\pm0.25$	$12.42^{a}\pm0.23$
T10	$12.82^{a}\pm0.41$	$12.19^{ab}\pm0.40$
CD	0.55	0.55
SE(m)	0.19	0.21

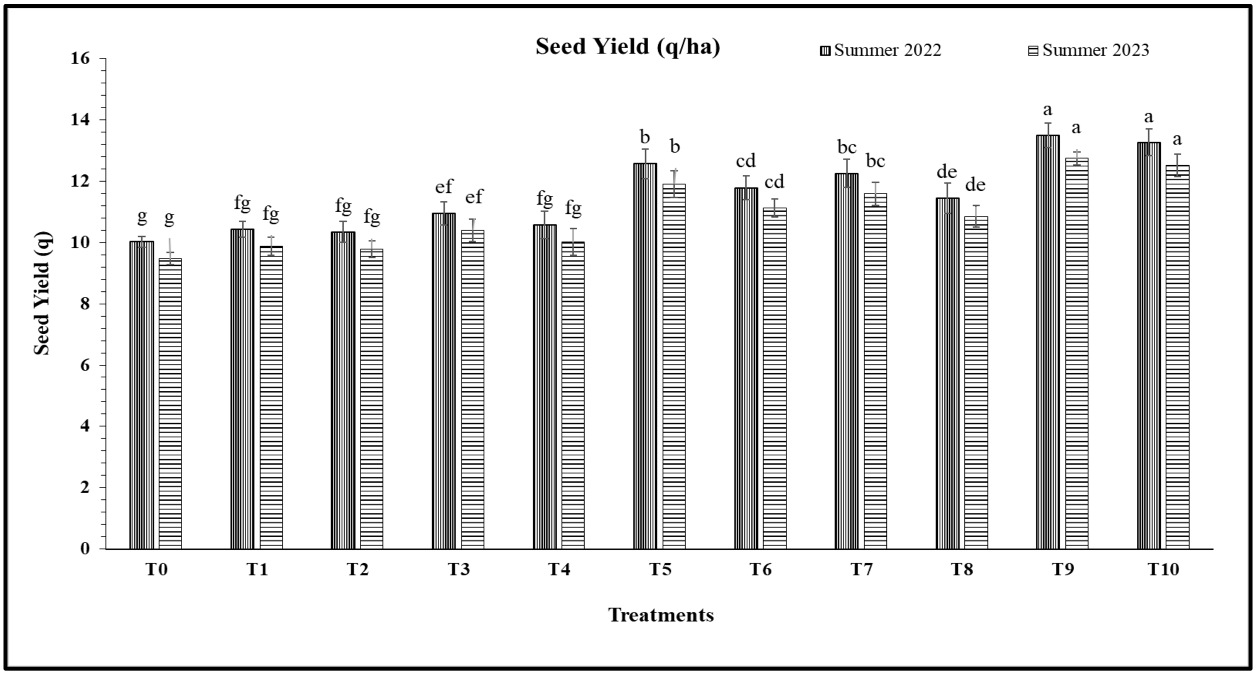


Figure 4.3.5.1a Effect of various treatments on seed yield (q/ha) in mung bean during *Summer* season and 2023

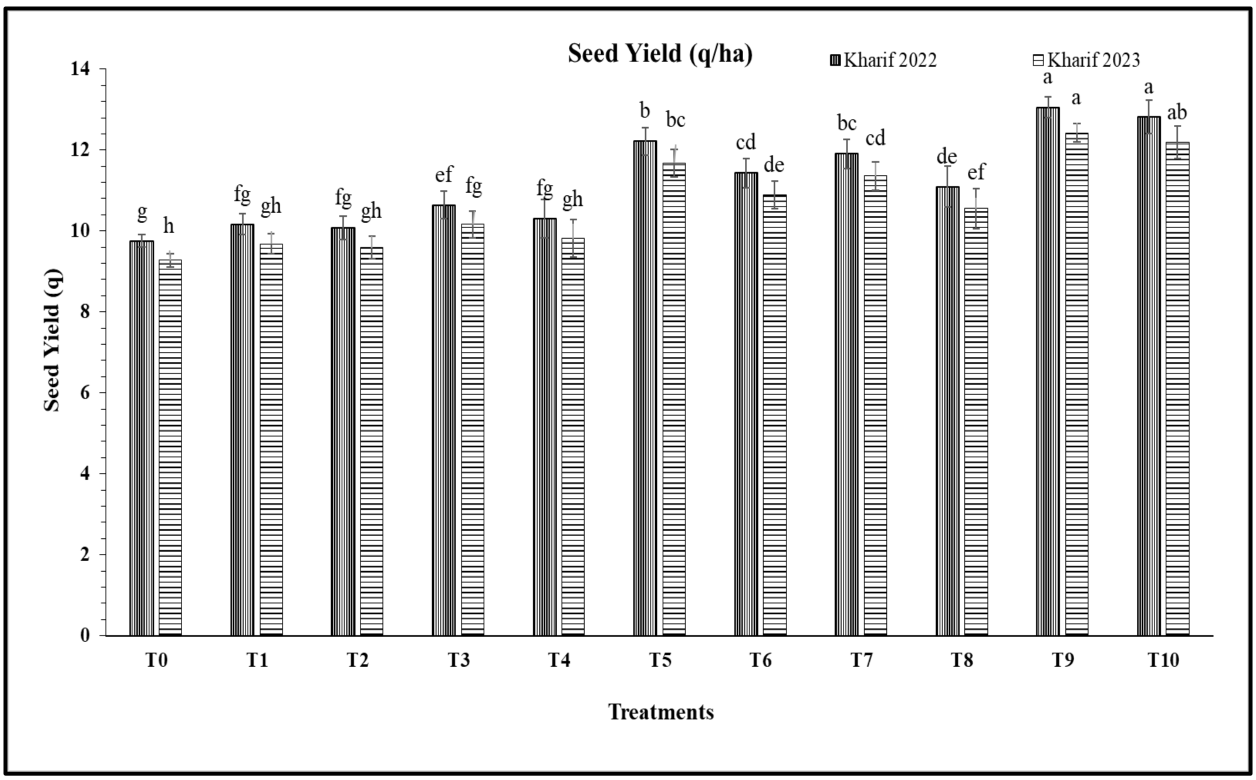


Figure 4.3.5.2a Effect of various treatments on seed yield (q/ha) in mung bean during *Kharif* season 2022 and 2023

4.3.6 Harvest index (%)

The impact of seed priming with gibberellin, salicylic acid, along with zinc and boron foliar application on harvesting index (%) was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of harvesting index (%) was taken by analysis (Table 4.3.6., 4.3.6.2, figure 4.3.6.1a, 4.3.6.2a). In 2022 and 2023 there was a considerable disparity in the percentage harvesting index (%) by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that the maximum harvest index was found in T9 (22.72) followed by (T10) (22.42). The minimum seed yield was found in control (T0) (19.49). The percentage of harvesting index (%) was increased in T9 by 16.6% as compared to the control T0. It was also observed that percentage of harvesting index (%) was lowest in control (T2) i.e. 10.5% respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. Similarly, it was found that the treatment T6 (i.e. foliar application of boron in Gibberellin primed seed plants) enhanced the percentage of harvesting index (%) by 6.9% when compared with treatment T4 i.e. individual foliar application of boron. In *Summer* 2023, it was recorded that the maximum harvest index was found in T9 (21.48) followed by (T10) (21.13). The minimum seed yield was found in control (T0) (18.37). The percentage of harvesting index (%) was significantly increased in treatment T9 (i.e. combined foliar application of Zinc and boron in gibberellin primed seed plants) 16.9% respectively as compared to control (T0). Similarly, it was found that the percentage of number harvesting index (%) in treatment T7 increased by 7% when compared with treatment T3 (i.e. individual foliar application zinc). It was also observed that percentage of harvesting index (%) was lowest in treatment T1 (i.e. individual application of gibberellin primed seeds) i.e. 7.6% when compared with treatment (T6). In both 2022-2023 *Summer* season, T9 had the highest harvest index, although it decreased slightly from 22.72 in 2022 to 21.48 in 2023. The percentage increase relative to the control slightly increased from 16.6% in 2022 to 16.9% in 2023.

Table 4.3.6.1 The Effect of various treatment on harvest index (%) in mung bean during *Summer* season 2022 and 2023

Treatments	Harvest index (%) *Summer* 2022	Harvest index (%) *Summer* 2023
T0	19.49^{e}±0.17	18.37^{f}±0.24
T1	19.67^{e}±0.29	18.54^{f}±0.44
T2	19.60^{e}±0.58	18.46^{f}±0.45
T3	20.19^{de}±0.46	19.09^{ef}±0.47
T4	19.84^{e}±0.59	18.72^{f}±0.56
T5	21.87^{ab}±1.03	20.69^{ab}±0.91
T6	21.20^{bcd}±0.55	19.94^{bcd}±0.44
T7	21.66^{abc}±1.03	20.43^{abc}±0.94
T8	20.50^{cde}±1.06	19.37^{cde}±0.80
T9	22.72^{a}±0.29	21.48^{a}±0.38
T10	22.40^{ab}±0.63	21.13^{ab}±0.59
CD	1.12	1.03
SE(m)	0.38	0.35

In *Kharif* 2022 the percentage of harvesting index (%) was significantly increased in treatment T10 i.e. 14.9% respectively as compared to control (T0). Similarly, it was found that the percentage of harvesting index (%) in treatment T5 increased by 12.3% when compared with treatment T1 i.e.. It was also observed that percentage of harvesting index (%) was lowest in treatment (T4) i.e. 2.9% when compared with treatment (T8). In *Kharif* 2023 it was recorded that the percentage of harvesting index (%) was increased in T10 by 14.5% respectively as compared to treatment T0 (control). It was also observed that percentage of harvesting index (%) was lowest in control (T3) i.e. 8.5% when compared with treatment (T5). Similarly, it was found that the the percentage of harvesting index (%) in treatment T8 increased by 4.1% when compared with treatment T2 i.e. individual priming of seeds with salicylic acid. T10 showed consistent performance with a slight decrease in the percentage increase from 14.9% in 2022 to 14.5% in 2023. T5 had a significant impact in 2022 with a 12.3% increase compared to T8's 4.1% increase in 2023. Both the *Summer* and *Kharif* season crop of mung bean harvesting index (%) was slightly greater in *Summer* season as we compare to *Kharif* season, harvesting index (%) in the crop of *Summer* season was higher. GA application can stimulate flowering and pod development in mung bean plants. This can lead to increased pod set and potential for higher grain yield, consequently improving the Harvest Index. Zinc and boron are micronutrients essential for various physiological processes, including photosynthesis and reproductive development **(Kuzbakova *et al.,* 2022)**. Their foliar application ensures that mung bean plants have sufficient nutrients to allocate resources efficiently, maximizing grain yield relative to total biomass. A higher total biomass usually results in a higher potential grain yield. However, the Harvest Index reflects the efficiency with which this biomass is converted into grain. The results were supported by **Singh *et al.,* 2020; Shafiq *et al.,* 2021; Navya *et al.,* 2021 and Negi *et al.,* 2023.** This is the ratio of grain yield to total biomass, which results in improved yield efficiency. Taller plants with a well-developed canopy are capable of capturing more sunlight, potentially enhancing photosynthesis and biomass accumulation. The Harvest Index measures how effectively these resources are used for grain production. Foliar application of zinc and boron can improve flower retention, pollination, and pod filling, thereby increasing the grain-to-total-biomass ratio (**Haritha *et al.,* 2020; Embadwar *et al.,* 2023**).

Table 4.3.6.2 Effect of various treatments on harvest index (%) in mung bean during *Kharif* season 2022 and 2023

Treatments	Harvest index (%) *Kharif* 2022	Harvest index (%) *Kharif* 2023
T0	18.60^{e}±0.38	18.10^{d}±0.15
T1	18.80^{e}±0.57	18.32^{d}±0.31
T2	18.72^{e}±0.73	18.24^{d}±0.47
T3	19.28^{de}±0.78	18.81^{cd}±0.42
T4	18.98^{de}±1.04	18.50^{d}±0.64
T5	20.91^{ab}±0.37	20.40^{ab}±0.73
T6	20.22^{bcd}±0.73	19.67^{bc}±0.47
T7	20.68^{abc}±0.57	20.17^{ab}±0.84
T8	19.53^{cde}±0.79	18.98^{cd}±1.06
T9	21.68^{a}±0.69	21.04^{a}±0.04
T10	21.37^{ab}±0.86	20.73^{ab}±0.61
CD	1.08	0.98
SE(m)	0.37	0.33

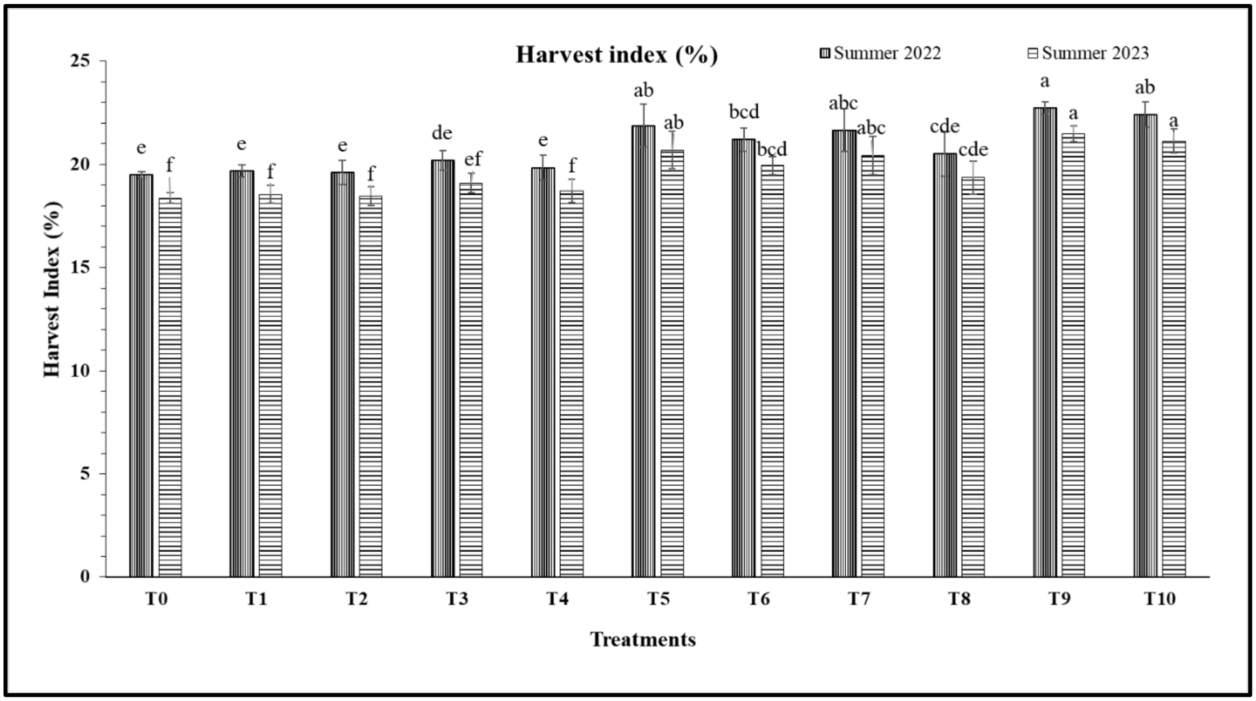


Figure 4.3.6.1a Effect of various treatments on harvest index (%) in mung bean during *Summer* season 2022 and 2023

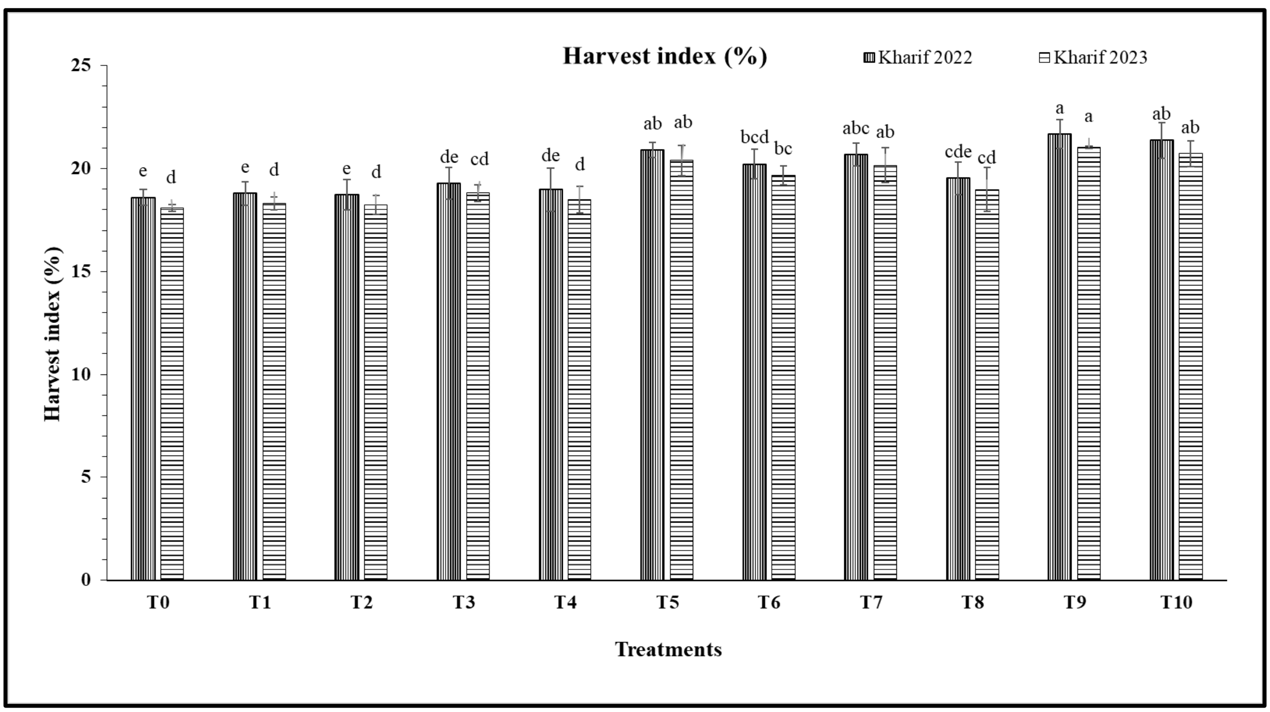


Figure 4.3.6.2a Effect of various treatments on harvest index (%) in mung bean during *Kharif* season 2022 and 2023

4.4 Seed Protein (g)

The effects of seed priming with gibberellin, salicylic acid, along with foliar application of zinc along with boron on seed protein (microgram/ml) was observed in *Summer* and *Kharif* season in mung bean plant during 2022 and 2023. The data of seed protein (microgram/ml) was taken after harvest (Table 4.4.1, 4.4.2 and Figure 4.4.1a, 4.4.2a). In 2022 and 2023, the percentages were significantly different.of seed protein (g) by phytohormones priming and foliar application of micronutrients. In *Summer* 2022 it was recorded that the highest seed protein was found in T9 (26.49) followed by (T10) (26.32). The minimum seed protein was found in control (T0) (22.47). The percentage of seed protein (g) was increased in T9 by 15.7% respectively as compared to the treatment T0 (control). It was also observed that percentage of seed protein (g) was lowest in control (T2) i.e. 12.2% respectively when compared with treatment (T7) i.e. foliar application of zinc in salicylic acid primed seed plants. Similarly, it was found that the treatment T6 (i.e. foliar application of boron in Gibberellin primed seed plants) enhanced the percentage of seed protein (g) by 5.8% when compared with treatment T4 i.e. individual foliar application of boron. In *Summer* 2023 the percentage of seed protein (g) was significantly increased in treatment T9 (i.e. combined foliar application of Zinc and boron in gibberellin primed seed plants) 14.8% respectively as compared to control (T0). Similarly, it was found that the treatment T7 enhanced the percentage of seed protein (g) by 1.4% respectively when compared with treatment T3 (i.e. individual foliar application zinc). It was also observed that percentage of seed protein (g) was lowest in treatment (T6) i.e. 8.6% respectively when compared with treatment (T1) (i.e. individual application of gibberellin primed seeds). In both the years T9 had the highest seed protein content, although it decreased slightly from 26.49 in 2022 to 25.26 in 2023. The percentage increase relative to the control slightly decreased from 15.7% in *Summer* 2022 to 14.8% in *Summer* 2023.

Table 4.4.1 Effect of various treatments on Seed protein (g) of mung bean during *Summer* season 2022 and 2023

Treatments	Seed Protein *Summer* 2022	Seed Protein *Summer* 2023
T0	22.47^{b}±2.28	21.72^{b}±1.79
T1	23.37^{ab}±2.51	22.44^{ab}±2.27
T2	22.81^{ab}±2.70	22.05^{ab}±2.20
T3	24.4^{ab}±1.15	23.67^{ab}±1.26
T4	23.87^{ab}±1.80	23.1^{ab}±1.76
T5	25.67^{ab}±1.90	24.71^{ab}±1.88
T6	25.34^{ab}±1.70	24.38^{ab}±1.65
T7	25.59^{ab}±1.47	24^{ab}±1.50
T8	24.99^{ab}±3.00	23.4^{ab}±2.00
T9	26.49^{a}±1.00	25.48^{a}±1.76
T10	26.32^{a}±0.98	25.15^{a}±1.96
CD	3.14	2.81
SE(m)	1.07	0.95

In *Kharif* 2022 the percentage of total soluble protein (g) was significantly increased in treatment T10 i.e. 14.2% respectively as compared to control (T0). Similarly, it was found that the treatment T5 enhanced the percentage of seed protein (g) by 9.3% respectively when compared with treatment T1. It was also observed that percentage of seed protein (g) was lowest in treatment (T4) i.e. 4.7% respectively when compared with treatment (T8). In *Kharif* 2023 it was recorded that the maximum seed protein was found in T9 (25.26) followed by (T10) (24.93). The minimum seed protein was found in control (T0) (21.25). The percentage of seed protein (g) was increased in T10 by 13.1% respectively as compared to the treatment T0 (control). It was also observed that percentage of seed protein (g) was lowest in control (T3) i.e. 4.7% respectively when compared with treatment (T5). Similarly, it was found that the treatment T8 enhanced the percentage of seed protein (g) by 8.6% respectively when compared with treatment T2. T10 showed a consistent performance with a slight decrease in the percentage increase from 14.2% in *Kharif* 2022 to 13.1% in 2023. T5 had a significant impact in *Kharif* 2022, while T8 showed improvement in *Kharif* 2023. T9 and T10 consistently had high seed protein contents in both *Summer* and *Kharif* seasons. T9 was particularly effective in the *Summer* seasons, while T10 showed strong performance across all *Kharif* seasons. Seed protein (g) in the crop of *Summer* season was higher. Mung bean seeds priming with gibberellic acid (GA) combined with foliar applications of zinc (Zn) and boron (B) can significantly enhance the protein content in the seeds. These treatments promote overall plant growth, improve metabolic activities, and ensure efficient nutrient uptake and utilization, leading to higher protein synthesis **(Nandan *et al.,* 2021)**. GA can enhance the synthesis of proteins by stimulating the growth and metabolic activity of the plant, leading to better development and nutrient assimilation. Enhanced vegetative growth and improved photosynthetic efficiency due to GA priming provide more energy and substrates for protein synthesis in the seeds. These findings are consistent with those of **Chakraborty *et al*. (2021), Islam *et al.* (2021), and Iqbal *et al.* (2023)**. The application of zinc serves as a cofactor for ribosomal RNA and several enzymes essential for amino acid synthesis and protein assembly. Meanwhile, boron affects the movement of sugars and amino acids within the plant, boosting the availability of precursors needed for protein synthesis. Protein content in mung beans is a key indicator of their nutritional value, with higher protein levels enhancing their value as a dietary protein source. Increased protein content in seeds often correlates with improved yield, as it reflects healthier plants with better nutrient status (**Krishna *et al.,* 2022Mahesh *et al.,* 2023; Dhaliwal *et al.,* 2023; Selim *et al.,* 2023).**

Table 4.4.2 Effect of various treatments on seed protein (g) of mung bean during *Kharif* season 2022 and 2023

Treatments	Seed Protein *Kharif* 2022	Seed Protein *Kharif* 2023
T0	22.13^{b}±2.00	21.25^{b}±1.83
T1	23.03^{ab}±2.02	22.17^{ab}±1.96
T2	22.47^{ab}±2.70	21.75^{ab}±2.65
T3	24.13^{ab}±1.61	23.33^{ab}±1.26
T4	23.6^{ab}±1.80	22.83^{ab}±1.83
T5	25.4^{ab}±1.91	24.43^{ab}±1.88
T6	25.07^{ab}±1.70	24.1^{ab}±1.74
T7	25.3^{ab}±1.47	24.38^{ab}±1.50
T8	24.7^{ab}±2.51	23.8^{ab}±2.65
T9	26.13^{a}±1.03	25.26^{a}±1.76
T10	25.80^{a}±1.97	24.93^{a}±1.94
CD	2.95	2.69
SE(m)	1.00	0.91

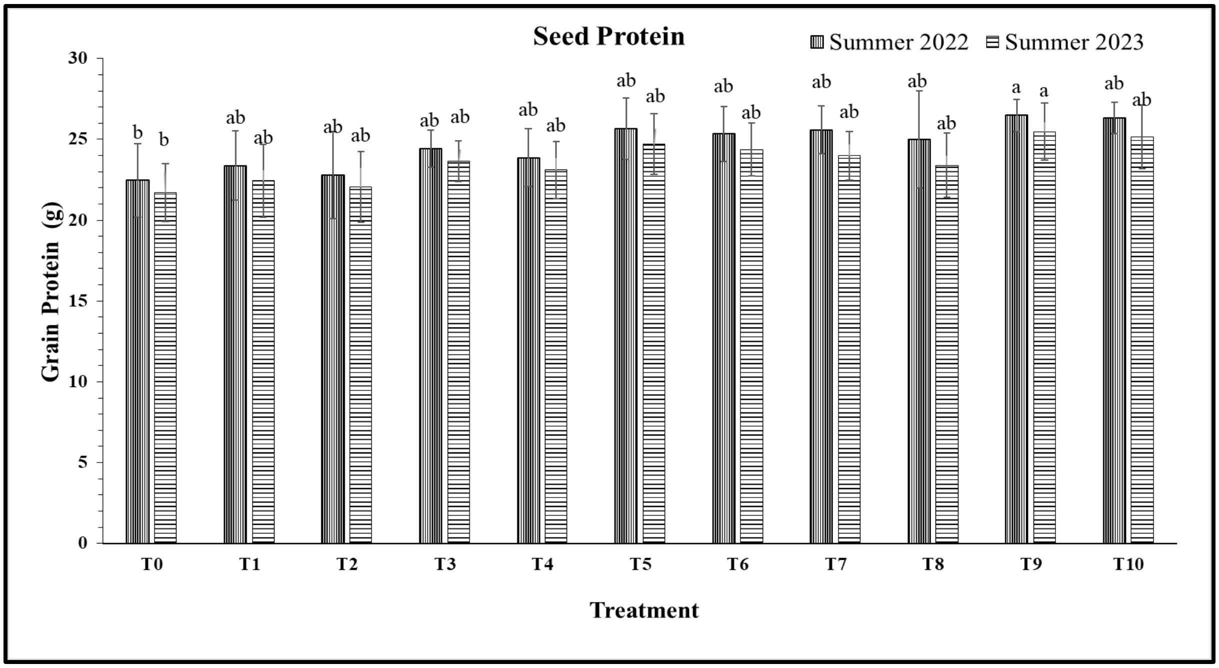


Figure 4.4.1a Effect of various treatments on Seed protein (g) of mung bean during *Summer* season 2022 and 2023

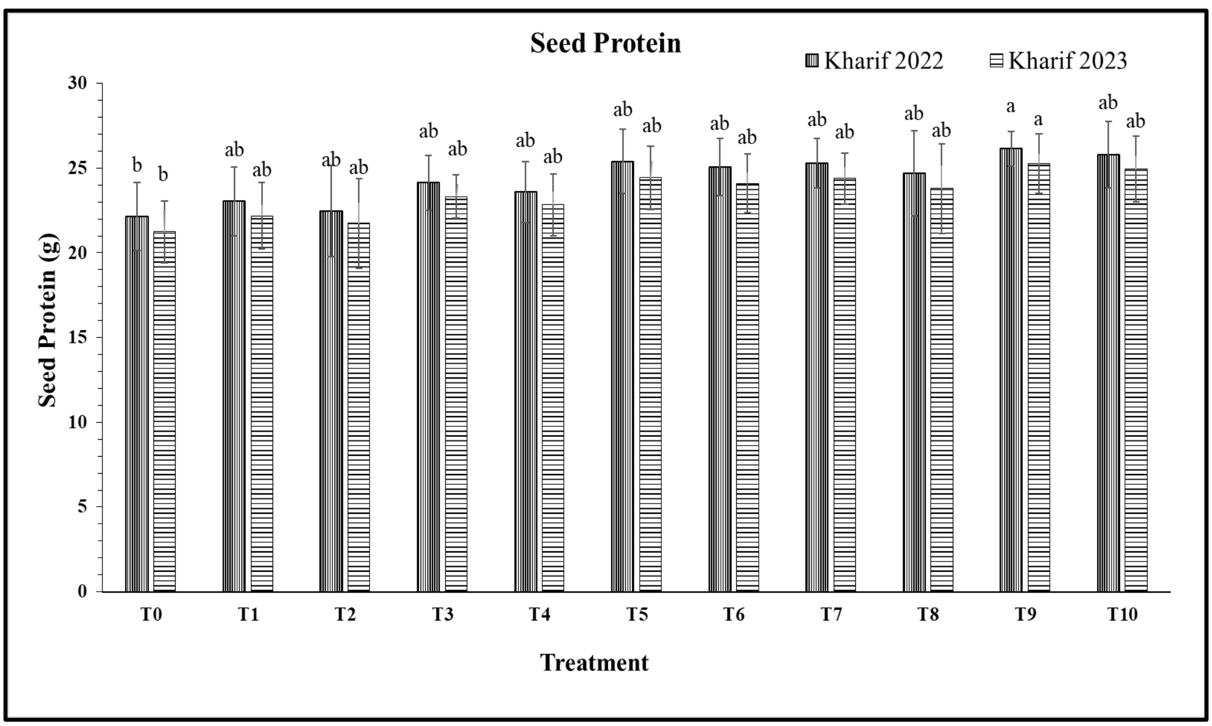


Figure 4.4.2a Effect of various treatments on seed protein (g) of mung bean during *Kharif* season 2022 and 2023

4.4.2 Amino acids

The effect of priming seeds with gibberellin, salicylic acid and micronutrients foliar application on amino acid (arginine and tryptophan) was observed in *Summer* and *Kharif* season in mung bean plant during 2022. The data of amino acids was taken after harvest (Table 4.4.1, 4.4.2 and Figure 4.4.1a, 4.4.2a). In *Summer* 2022, it was recorded that the maximum amino acid (arginine) was found in T9 (0.68) followed by (T10) (0.63). The minimum seed protein was found in control (T0) (0.08). The percentage of amino acid (arginin) was increased in T9 by 87.4% respectively as compared to the control T0. It was also observed that percentage of amino acid (arginine) was lowest in control (T2) i.e. 79.7% respectively when compared with treatment (T7). Similarly, it was found that the treatment T6 enhanced the percentage of amino acid (arginine) by 11.1% when compared with treatment T4. In *Summer* 2022 it was recorded that the maximum amino acid (tryptophan) was found in T9 (0.068) followed by (T10) (0.063). The minimum amino acid (tryptophan) was found in control (T0) (0.057). The percentage of amino acid (tryptophan) was increased in T9 by 16.5% respectively as compared to the control T0. It was also observed that percentage of amino acid (tryptophan) was lowest in control (T2) i.e. 5.6% respectively when compared with treatment (T7). Similarly, it was found that the treatment T6 enhanced the percentage of amino acid (tryptophan) by 11.6% when compared with treatment T4.

Table 4.4.2.1 Effect of various treatments on amino acids (arginine) of mung bean during *Summer* season 2022

Treatments	Arginine (%)	Tryptophan (%)
T0	0.086	0.058
T1	0.302	0.059
T2	0.270	0.058
T3	0.461	0.054
T4	0.437	0.051
T5	0.518	0.064
T6	0.491	0.058
T7	0.485	0.061
T8	0.462	0.055
T9	0.683	0.069
T10	0.638	0.063

In *Kharif* 2022, it was recorded that the maximum amino acid (arginine) was found in T9 (0.46) followed by (T10) (0.063). The minimum amino acid (arginine) was found in control (T0) (0.06). The percentage of amino acid (arginine) was significantly increased in treatment T10 (i.e. combined Zinc and boron (B) foliar application in salicylic acid primed seed plants) 84.3% respectively as compared to control (T0). Similarly, it was found that the treatment T5 enhanced the percentage of amino acid (arginine) by 35.6% respectively when compared with treatment T1 (i.e. individual application of gibberellin primed seed plants). It was also observed that percentage of amino acid (arginine) was lowest in treatment (T4) i.e. 13.2% respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants). In *Kharif* 2022 the percentage of amino acid (tryptophan) was significantly increased in treatment T10 (i.e. combined Zinc and boron (B) foliar application in salicylic acid primed seed plants) 25.4% respectively as compared to control (T0). Similarly, it was found that the treatment T5 enhanced the percentage of amino acid (tryptophan) by 13.4% respectively when compared with treatment T1 (i.e. individual application of gibberellin primed seed plants). It was also observed that percentage of amino acid (tryptophan) was lowest in treatment (T4) i.e. 1.8% respectively when compared with treatment (T8) (i.e. foliar application of boron in salicylic acid primed seed plants). Overall, both *Kharif* seasons indicated that while combined foliar treatments (T9, T10) remained the most effective for enhancing amino acid levels, there were variations in magnitude likely influenced by seasonal growing conditions and environmental factors.GA priming, coupled with foliar applications of Zn and B, significantly influences the levels of tryptophan in mung beans. These treatments effect enhance the metabolic activities and nutrient uptake of the plants, leading to higher amino acid synthesis. Improved levels of tryptophan and arginine contribute to the nutritional quality of mung beans and are closely linked to various biochemical parameters such as protein content, enzyme activities, and stress responses. The similar results were obtained by **Tahir *et al.,* 2019; Pandey *et al.,* 2024; Karimunnisa *et al.,* 2021.** GA can enhance the synthesis of tryptophan and arginine by modulating the activity of enzymes involved in the shikimate pathway, which is responsible for the production of aromatic amino acids. Foliar application of zinc helps in the proper functioning of tryptophan synthase, the enzyme directly responsible for the production of tryptophan and zinc is also responsible for the proper functioning of enzymes such as argininosuccinate synthase and argininosuccinate lyase, which are directly involved in arginine biosynthesis. The application of Boron influences the translocation of sugars and amino acids within the plant, enhancing the availability of precursors for amino acid synthesis. The results are in line with those of **Ravindra *et al.,* 2022; Quddus *et al.,* 2020;** and **Kachare *et al.,* 2022.** Tryptophan is an essential amino acid that the human body cannot produce and must be obtained through diet. It serves as a precursor for serotonin and niacin (Vitamin B3), making it crucial for neurological health. Arginine is also important in human nutrition, playing a key role in protein synthesis, the urea cycle, and the production of nitric oxide, which supports cardiovascular health. The shikimate pathway, responsible for synthesizing tryptophan and arginine, relies on proper nutrition and regulatory mechanisms influenced by gibberellic acid (GA), zinc (Zn), and boron (B). Improved tryptophan levels can enhance the plant's ability to withstand biotic and abiotic stresses, leading to better growth and yield. Arginine plays a role in plant stress responses as a precursor for polyamines and nitric oxide, both of which are involved in stress tolerance mechanisms. The results are in agreement with **Hasan *et al.,* 2020; Parveen *et al.,* 2023; Nandan *et al.,* 2021; Wang *et al.,* 2020**.

Table 4.4.2.2 Effect of various treatments on amino acids (tryptophan) of mung bean during *Kharif* season 2022

Treatments	Arginine (%)	Tryptophan (%)
T0	0.066	0.034
T1	0.211	0.035
T2	0.190	0.034
T3	0.291	0.036
T4	0.267	0.035
T5	0.328	0.040
T6	0.301	0.037
T7	0.325	0.038
T8	0.302	0.036
T9	0.463	0.045
T10	0.418	0.042

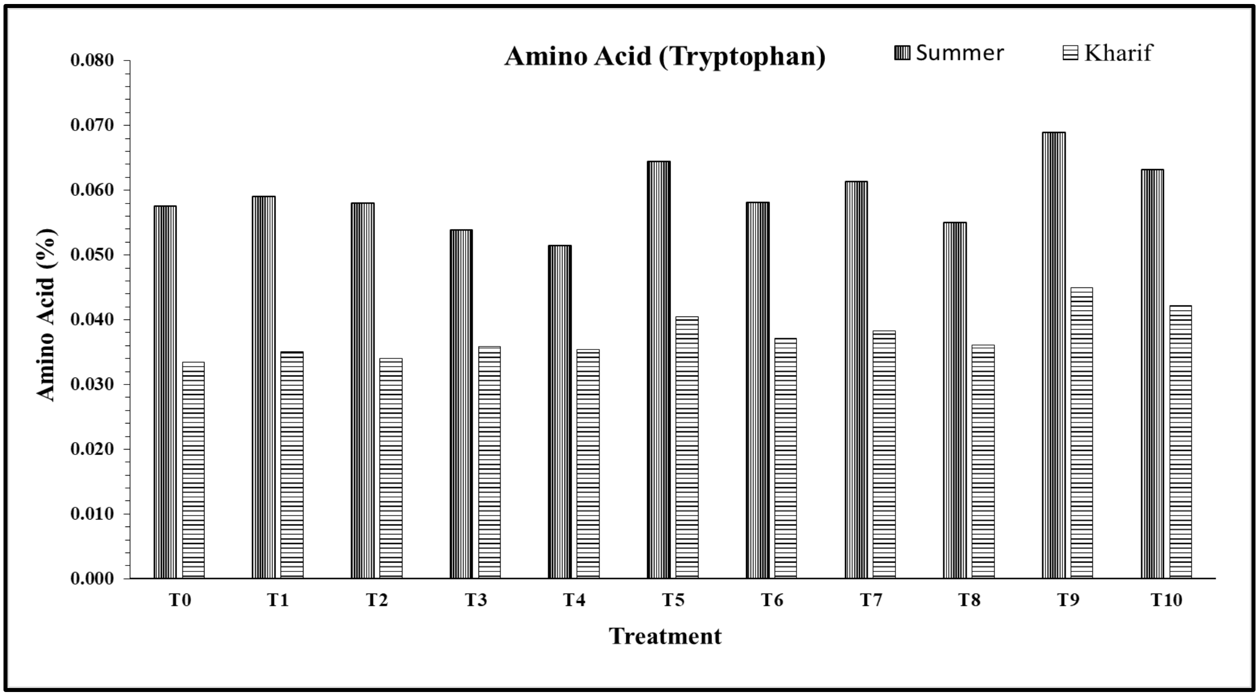


Figure 4.4.2.1a Effect of various treatments on amino acids (tryptophan) of mung bean during *Summer* and *Kharif* season 2022

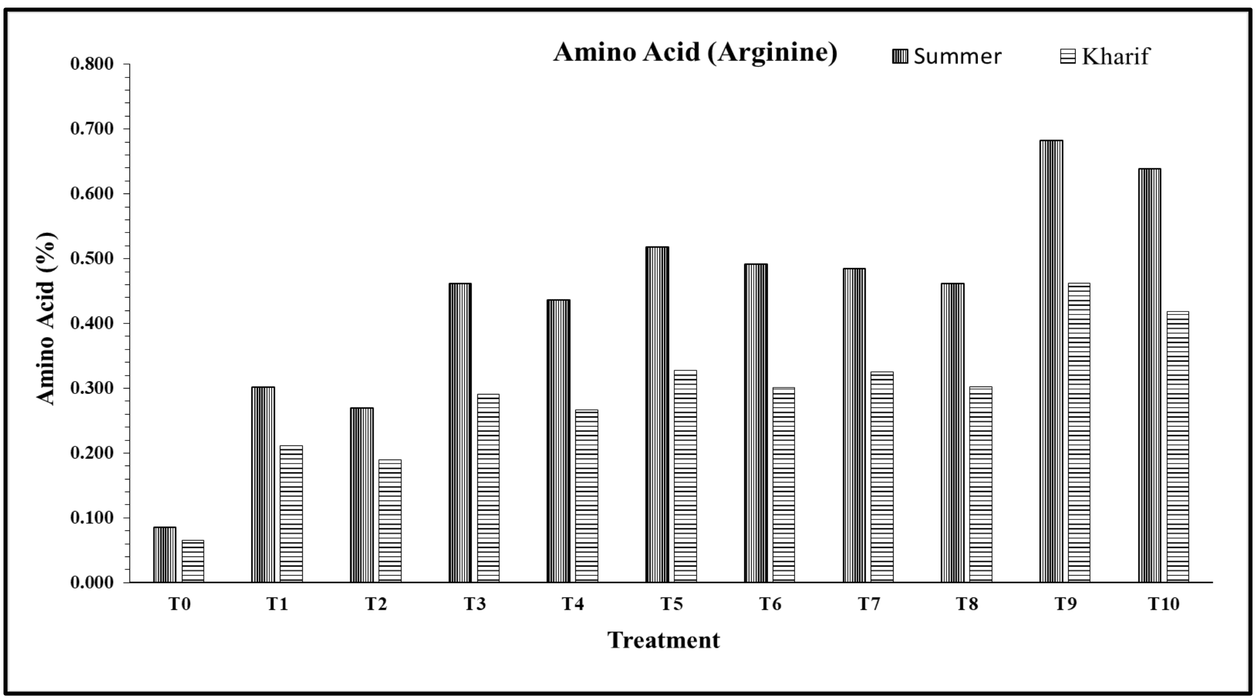


Figure 4.4.2.2a Effect of various treatments on amino acids (arginine) of mung bean during *Summer* and *Kharif* season 2022

4.5 Economic analysis

4.5.1 Cost of cultivation (Rs/ha)

The effect of seed priming with gibberellin, salicylic acid and foliar application of zinc and boron on cost of cultivation in mung bean At harvest during *Summer* 2022 and 2023 sown in Table (4.5.1) and Table (4.5.2). In 2022 and 2023, there was a significant difference of cost of cultivation in mung bean priming by phytohormones and foliar application of micronutrients. In 2022 and 2023 maximum cost of cultivation was found in treatment T9 i.e. (priming seeds with gibberellic acid and combined foliar application of zinc and boron) 23092.4 Rs/ha followed by treatment T10 22968.65 Rs/ha. The minimum cost of cultivation was found in treatment T0 (22207.4 Rs/ha). The single foliar application of micronutrient in primed seeds maximum cost of cultivation was found in treatment T5 (seed priming with gibberellic acid and foliar application with zinc) i.e. 22867.4 Rs/ha followed by treatment T7 (priming seeds with salicylic acid and foliar application of zinc), T6 and T8 i.e. 22743.65, 22567.4 and 22443.65 Rs/ha.

4.5.2 Gross Return (Rs/ha)

The effect of seed priming with gibberellin, salicylic acid and foliar application of zinc and boron on gross return (Rs/ha) in mung bean At harvest during *Summer* 2022 and 2023 sown in Table (4.5.1) and Table (4.5.2).. In *Summer* 2022, there was a significant difference of gross return (Rs/ha) in mung bean priming by phytohormones and foliar application of micronutrients. In 2022 primed seeds with combined foliar application of zinc and boron the gross return (Rs/ha) in T9 and T10 was 70720 and 69450 (Rs/ha). In the single foliar application of micronutrient in primed mung bean the gross return (Rs/ha) in treatment T5, T6, T7 and T8 was 65678.9, 61399.4, 63956.2 and 59568 Rs/ha respectively. In *Summer* 2023, there was a significant difference of gross return (Rs/ha) in mung bean priming by phytohormones and foliar application of micronutrients. In 2023 primed seeds with combined foliar application of zinc and boron the maximum gross return (Rs/ha) was found in treatment T9 followed by T10 i.e. 66640 and 65370 (Rs/ha). In the single foliar application of micronutrient in primed mung bean the gross return (Rs/ha) in treatment T5, T6, T7 and T8 was 62052, 57772.8, 60329.6 and 56304 Rs/ha respectively. The minimum gross return (Rs/ha) was found in treatment T0 (control) i.e. 48824 Rs/ha. In *Kharif* 2022 primed seeds with combined foliar application of zinc and boron the gross return (Rs/ha) in T9 and T10 was 61435.7

and 57518.9 (Rs/ha). In the single foliar application of micronutrient in primed mung bean the gross return (Rs/ha) in treatment T5, T6, T7 and T8 was 56430.9, 55052.8, 55342.9 and 53021.8 Rs/ha respectively. The minimum gross return (Rs/ha) was found in treatment T0 (control) i.e. 50347.2 Rs/ha. In *Kharif* 2023, there was a significant difference of gross return (Rs/ha) in mung bean priming by phytohormones and foliar application of micronutrients. In *Kharif* 2023 primed seeds with combined foliar application of zinc and boron the maximum gross return (Rs/ha) was found in treatment T9 followed by T10 i.e. 63593.6 and 64862.9 (Rs/ha). In the single foliar application of micronutrient in primed mung bean the gross return (Rs/ha) in treatment T5, T6, T7 and T8 was 60801, 56521.6, 59078.4 and 54690.1 Rs/ha respectively. The minimum gross return (Rs/ha) was found in treatment T0 (control) i.e. 47726.9 Rs/ha.

4.5.3 Net Return (Rs/ha)

The effect of seed priming with gibberellin, salicylic acid and foliar application of zinc and boron on net return (Rs/ha) in mung bean at harvest during *Summer* 2022 and 2023 sown in Table (4.5.1) and Table (4.5.2). In 2022 and 2023, there was a significant difference of net return (Rs/ha) in mung bean priming by phytohormones and foliar application of micronutrients. In *Summer* 2022 maximum net return (Rs/ha) was found in treatment T9 i.e. (priming seeds with gibberellic acid and combined foliar application of zinc and boron) 47627.6 Rs/ha followed by treatment T10 (46482 Rs/ha). The minimum net return (Rs/ha) was found in treatment T0 (29608.6 Rs/ha). In the single foliar application of micronutrient in primed mung bean the net return (Rs/ha) in treatment T5, T7, T6 and T8 was 42811.5, 41212.6, 38832.1 and 37124.4 Rs/ha respectively. In *Summer* 2023, there was a significant difference of net return (Rs/ha) in mung bean priming by phytohormones and foliar application of micronutrients. In 2023 primed seeds with combined foliar application of zinc and boron the maximum net return (Rs/ha) was found in treatment T9 followed by T10 i.e. 43547.60 and 42402.02 (Rs/ha). In the single foliar application of micronutrient in primed mung bean the net return (Rs/ha) in treatment T5, T7, T6 and T8 was 39184.87, 37585.95, 35205.40 and 33860.35 Rs/ha respectively. The minimum net return (Rs/ha) was found in treatment T0 (control) i.e. 17596 Rs/ha. In *Kharif* 2022 primed seeds with combined foliar application of zinc and boron the in T9 and T10 was 38343.3 and 34550.3 (Rs/ha). In the single foliar application of micronutrient in primed mung bean the net return (Rs/ha) in treatment T5, T7, T6 and T8 was 33563.5, 32599.3, 32485.4 and 30578.2 Rs/ha respectively. The minimum net return (Rs/ha) was found in treatment T0 (control) i.e. 28139.80 Rs/ha. In *Kharif* 2023, there was a significant difference of net return (Rs/ha) in mung bean priming by phytohormones and foliar application of micronutrients. In *Kharif* 2023 primed seeds with combined foliar application of zinc and boron the maximum net return (Rs/ha) was found in treatment T10 followed by T9 i.e. 41894.28 and 40501.20 (Rs/ha). In the single foliar application of micronutrient in primed mung bean the net return (Rs/ha) in treatment T5, T7, T6 and T8 was 37933.67, 36334.75, 33954.20 and 32246.48 Rs/ha respectively. The minimum net return (Rs/ha) was found in treatment T0 (control) i.e. 25519.53 Rs/ha.

4.5.4 B:C Ratio

The influence of seed priming with gibberellin, salicylic acid and foliar application of zinc and boron on net B:C ratio in mung bean At harvest during *Summer* 2022 and 2023 sown in Table (4.5.1) and Table (4.5.2). In 2022 and 2023, there was a significant difference of B:C ratio in mung bean priming by phytohormones and foliar application of micronutrients. In *Summer* 2022 maximum B:C ratio was found in treatment T9 i.e. (priming seeds with gibberellic acid and combined foliar application of zinc and boron) 2.06 followed by treatment T10 2.02. The minimum B:C ratio was found in treatment T0 1.33. In the single foliar application of micronutrient in primed mung bean the B:C ratio in treatment T5, T6, T7 and T8 was 1.87, 1.81, 1.72 and 1.65 respectively. In *Summer* 2023, there was a significant difference of B:C ratio in mung bean priming by phytohormones and foliar application of micronutrients. In *Summer* 2023 primed seeds with combined foliar application of zinc and boron the maximum B:C ratio was found in treatment T9 followed by T10 i.e. 1.89 and 1.85. In the single foliar application of micronutrient in primed mung bean the B:C ratio in treatment T5, T7, T6 and T8 was 1.71, 1.65, 1.56 and 1.51 respectively. The minimum B:C ratio was found in treatment T0 (control) i.e. 1.27. In *Kharif* 2022 primed seeds with combined foliar application of zinc and boron the B:C ratio in T9 and T10 was 1.66 and 1.50. In the single foliar application of micronutrient in primed mung bean the B:C ratio in treatment T5, T6, T7 and T8 was 1.47, 1.44, 1.43 and 1.36 respectively. The minimum B:C ratio was found in treatment T0 (control) i.e. 1.27. In *Kharif* 2023, there was a significant difference of B:C ratio in mung bean priming by phytohormones and foliar application of micronutrients. In *Kharif* 2023 primed seeds with combined foliar application of zinc and boron the maximum B:C ratio was found in treatment T10 followed by T9 i.e. 1.82 and 1.75. In the single foliar application of micronutrient in primed mung bean the B:C ratio in treatment T5, T6, T7 and T8 was 1.66, 1.60, 1.50 and 1.44 respectively. The minimum B:C ratio was found in treatment T0 (control) i.e. 1.15.

Table 4.5.1 Effect of various treatments on economic analysis in mung bean during *Summer* season 2022 and 2023

Treatments	***Summer* 2022**				***Summer* 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**
T0	22207.4	51816.0	29608.6	1.33	22207.4	48824.00	26616.60	1.20
T1	22342.4	54037.3	31694.9	1.42	22342.4	51045.33	28702.93	1.28
T2	22218.65	53529.6	31311.0	1.41	22218.65	50537.60	28318.95	1.27
T3	22732.4	56829.9	34097.5	1.50	22732.4	53837.87	31105.47	1.37
T4	22432.4	54762.7	32330.3	1.44	22432.4	51770.67	29338.27	1.31
T5	22867.4	65678.9	42811.5	1.87	22867.4	62052.27	39184.87	1.71
T6	22567.4	61399.5	38832.1	1.72	22567.4	57772.80	35205.40	1.56
T7	22743.65	63956.3	41212.6	1.81	22743.65	60329.60	37585.95	1.65
T8	22443.65	59568.0	37124.4	1.65	22443.65	56304.00	33860.35	1.51
T9	23092.4	70720.0	47627.6	2.06	23092.4	66640.00	43547.60	1.89
T10	22968.65	69450.7	46482.0	2.02	22968.65	65370.67	42402.02	1.85

Table 4.5.2 Effect of various treatments on economic analysis in mung bean during *Kharif* season 2022 and 2023

Treatments	*Kharif* 2022				*Kharif* 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
T0	22207.4	50347.2	28139.8	1.27	22207.4	47726.93	25519.53	1.15
T1	22342.4	52296.5	29954.1	1.34	22342.4	49957.33	27614.93	1.24
T2	22218.65	50628.3	28409.6	1.28	22218.65	49449.60	27230.95	1.23
T3	22732.4	50410.7	27678.3	1.22	22732.4	52568.53	29836.13	1.31
T4	22432.4	49395.2	26962.8	1.20	22432.4	50682.67	28250.27	1.26
T5	22867.4	56430.9	33563.5	1.47	22867.4	60801.07	37933.67	1.66
T6	22567.4	55052.8	32485.4	1.44	22567.4	56521.60	33954.20	1.50
T7	22743.65	55342.9	32599.3	1.43	22743.65	59078.40	36334.75	1.60
T8	22443.65	53021.9	30578.2	1.36	22443.65	54690.13	32246.48	1.44
T9	23092.4	61435.7	38343.3	1.66	23092.4	63593.60	40501.20	1.75
T10	22968.65	57518.9	34550.3	1.50	22968.65	64862.93	41894.28	1.82

CHAPTER V

SUMMARY AND CONCLUSION

This research work entitled " **Impact of Zinc and Boron Foliar Application on Growth and Yield in Primed Mung Bean (*Vigna radiata* L.)"** had been coordinate during the *Summer* and *Kharif* season of 2022 and repeated again in 2023 same seasons , at Research Farm of School of Agriculture, Lovely Professional University, situated in Phagwara (Punjab). Major challenges are encountered in pulse cultivation with regard to seed germination, seed emergence, plant mortality, and crop establishment. Each of these issues is linked to a reduction in pulse productivity. Priming seeds is a more effective method for increasing seed germination, seedling emergence, and plant stand, which contributes to the self-sufficiency of pulse production and a significant disparity exists between the global pulse productivity of 904 kg/ha and that of India (650 kg/ha) (Devi et al., 2021). This shows that there is substantial potential for the nation to enhance its pulse productivity. This discrepancy could potentially be attributed to substandard seed quality, inadequate soil management, suboptimal crop production methods, rainfed cultivation, and other biotic and abiotic influences. By ensuring a sufficient supply of high-quality seeds, implementing enhanced seed production techniques, and pre-sowing seed treatments such as priming and coating, the yield disparity can be reduced. Achieving favourable soil and atmospheric conditions for crop stand can be accomplished by enhancing seed germination performance via pre-sowing treatment. This research investigates the complex interaction between the foliar application of zinc and boron and its effects on primed mung beans. SML1827 and ML1808 cultivars were introduced by Punjab Agriculture University (PAU). Data were collected on days 30 and 60 DAS at various growth intervals and At harvest on various parameters like morphological, biochemical and yield attributing parameters of mung bean in *Summer* and *Kharif* season 2022 and 2023.

- In case of seed priming with phytohormones, in *Summer* 2022 and 2023 the mamimum germination percentage in mung bean field was recorded in treatment T1 (95.2%) (i.e. priming with gibberellic acid) followed by T9 and T2 or treatment T1, T6 and T8 in *Summer* 2023 when compared to control (T0). In *Kharif* 2022and 2023 maximum germination percentage was found in T9 (96.7%), T10 and T5 or treatment T6 (90%) and T9 in *Kharif*.

- In *Summer* 2022, the application of GA (gibberellic acid) (T9) increased the percentage of plant height by 33.3 and 16.1% at 30-days and 60-DAS as compared to the treatment T0 (control). In *Kharif* 2022, the application of GA (T9) in mung bean increased the percentage of plant height by 30.5, 14.5% at 30-days and 60-DAS9 when compared to the control (T0), In *Summer* 2023, the foliar application of Zinc and boron with priming of gibberellic acid i.e. (T9) increased the percentage of plant height by 35.3, 17.2% at 30-days and 60-DAS when compared to treatment T0 (control). In *Kharif* 2023, treatment (T9) increased the percentage of plant height by 44, 18.9% at 30-days and 60-DAS when compared to the treatment T0 (control).
- In *Summer* 2022, the application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage of fresh weight by 56.4 and 30.7% at 30-days and 60-DAS in mung bean plants as compared to treatment T0 (control). In *Kharif* 2022, combined foliar micronutrient application with SA priming in treatment (T10) increased the percentage of fresh weight by 45.5 at 30 DAS and 34.3% at 60 DAS when compared to the treatment T0 (control). In *Summer* 2023, the foliar application of Zinc and boron with priming of gibberellic acid i.e. (T9) increased the percentage of fresh weight by 37.9 and 31.6% at 30-days and 60-DAS when compared to treatment T0 (control). In *Kharif* 2023, treatment (T10) increased the percentage of fresh weight by 49.2 and 39.8% at 30-days and 60-DAS when compared to the control.
- In *Summer* 2022, the application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage of dry weight by 39.6 and 46.6% at 30-days and 60-DAS as compared to treatment T0 (control). In *Kharif* 2022, combined foliar micronutrient application with SA priming in treatment (T10) increased the percentage of dry weight by 32.3% at 30 DAS and 33.4% at 60 DAS in mung bean when compared to treatment T0 (control). In *Summer* 2023, the foliar application of Zinc and boron with priming of gibberellic acid i.e. (T9) increased the percentage of dry weight by 37.8 and 30.9% at 30-days and 60-DAS when compared to treatment T0 (control). In *Kharif* 2023, treatment (T10) increased the percentage of dry weight by 49.3 and 38.7% at 30-days and 60-DAS when compared to the control.
- In *Summer* 2022, the application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage of number of leaves by 28.5 and

24% at 30-days and 60-DAS as compared to treatment T0 (control). In *Kharif* 2022, combined foliar micronutrient application with SA priming in treatment (T10) increased the percentage of number of leaves by 21.5% at 30 DAS and 25.5% at 60 DAS when compared to treatment T0 (control). In *Summer* 2023, the foliar application of Zinc and boron with priming of gibberellic acid i.e. (T9) increased the percentage of number of leaves by 32.9 and 28% at 30-days and 60-DAS when compared to treatment T0 (control). In *Kharif* 2023, treatment (T10) increased the percentage of number of leaves by 28.3 and 25.8% at 30-days and 60-DAS when compared to the control.

- In *Summer* 2022, the application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage in number of branches by 34.7 and 33.3% at 30-days and 60-DAS as compared to treatment T0 (control). In *Kharif* 2022, combined foliar micronutrient application with SA priming in treatment (T10) increased the percentage in number of branches by 45.5% at 30 DAS and 36.6% at 60 DAS when compared to treatment T0 (control). In *Summer* 2023, the foliar application of mcronutrients with priming of gibberellic acid in mung bean i.e. (T9) increased the percentage in number of branches by 49.6 and 42.9% at 30-days and 60-DAS when compared to treatment T0 (control). In *Kharif* 2023, treatment (T10) increased the percentage in number of branches by 55.7 and 31.1% at 30-days and 60-DAS when compared to the control.
- In *Summer* 2022, the application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage in root length by 36.1 and 34.4% at 30-days and 60-DAS as compared to treatment T0 (control). In *Kharif* 2022, in mung bean crop combined foliar micronutrient application with SA priming in treatment (T10) increased the percentage in root length by 37.5% at 30 DAS and 27.9% at 60 DAS when compared to treatment T0 (control). In *Summer* 2023, the foliar application of micronutrients with priming of gibberellic acid i.e. (T9) increased the percentage in root length by 43.6 and 34.5% at 30-days and 60-DAS when compared to treatment T0 (control). In *Kharif* 2023, treatment (T10) increased the percentage in root length by 35.8 and 32.4% at 30-days and 60-DAS when compared to the control.
- In *Summer* 2022, the application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage in number of nodules by 45 and 37.6% at 30-days and 60-DAS as compared to treatment T0 (control). In *Kharif* 2022,

combined foliar micronutrient application with SA priming in treatment (T10) increased the percentage in number of nodules by 45.9 at 30 DAS and 41.5% at 60 DAS when compared to the treatment (T0) control. In *Summer* 2023, the foliar application of Zinc and boron with priming of gibberellic acid i.e. (T9) increased the percentage in number of nodules by 57 and 45.6% at 30-days and 60-DAS when compared to treatment T0 (control). In *Kharif* 2023, treatment (T10) increased the percentage in number of nodules by 60.9 and 48% at 30-days and 60-DAS when compared to the control.

- In *Summer* 2022, the application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage in leaf area index by 25.8 and 27.1% at 30-days and 60-DAS in mung bean crop as compared to treatment T0 (control). In *Kharif* 2022, combined foliar micronutrient application with SA priming in treatment (T10) increased the percentage in leaf area index by 25.2 at 30 DAS and 27.8% at 60 DAS when compared to the treatment (T0) control. In *Summer* 2023, the foliar application of Zinc and boron with priming of gibberellic acid i.e. (T9) increased the percentage in leaf area index by 27 and 30.3% at 30-days and 60-DAS when compared to treatment T0 (control). In *Kharif* 2023, treatment (T10) increased the percentage in leaf area index by 60.9 and 33.6% at 30-days and 60-DAS when compared to the control.
- In *Summer* 2022, the application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage in days to 50% flowering by 11.3% as compared to treatment T0 (control). In *Kharif* 2022, combined foliar micronutrient application with SA priming in treatment (T10) increased the percentage in days to 50% flowering by 9.4% in mung bean when compared to treatment T0 (control). In *Summer* 2023, the foliar application of Zinc and boron with priming of gibberellic acid i.e. (T9) increased the percentage in days to 50% flowering by 10.3% when compared to treatment T0 (control). In *Kharif* 2023, treatment (T10) increased the percentage in days to 50% flowering by 7.7% when compared to the control.
- In *Summer* 2022, the application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage in crop growth rate by 40 and 48.4% at 30-days and 60-DAS as compared to treatment T0 (control). In *Kharif* 2022, combined foliar micronutrient application with SA priming in treatment (T10) increased the percentage in crop growth rate by 32% at 30 DAS and 30.1% at 60 DAS when compared to the treatment (T0)

control (T0). In *Summer* 2023, the foliar application of Zinc and boron with priming of gibberellic acid i.e. (T9) increased the percentage in crop growth rate by 34 and 26.9% at 30-days and 60-DAS when compared to treatment T0 (control). In *Kharif* 2023, treatment (T10) increased the percentage in crop growth rate by 3 and 37.5% at 30-days and 60-DAS when compared to the control.

- In *Summer* 2022, the application phytohormone priming and foliar application of micronutrients in maximum relative growth rate 0.0077 g/g/day was found in treatment (T1) at 30days and 0.054 g/g/day was found maximum in 60 days. In *Kharif* 2022, foliar application of boron with SA priming in treatment (T8) 0.0044 g/g/day and treatment (T7) 0.060 g/g/day was found maximum relative growth rate at 30 and 60 days in mung bean. In *Summer* 2023, the foliar application of micronutrients (Zn+B) with priming of gibberellic acid i.e. (T9) was found 0.054 g/g/day maximum relative growth at 30Days and treatment T0 0.006 g/g/day was found maximum in 60 days. In *Kharif* 2023 the maximum relative growth rate 0.054 g/g/day were recorded by treatment T9 at 30 days and 0.0064 g/g/day were recorded by treatment T0 at 60 days respectively.
- In *Summer* 2022, the maximum and minimum net assimilation ratio 9.78 mg/cm^2/day were recorded by treatment T10 at 30 days and 1.15 mg/cm^2/day were recorded by treatment T9 at 60 days. . In *Kharif* 2022 the net assimilation ratio at 30 days was found maximum in treatment T10 i.e. 7.41 mg/cm^2/day and 1.07 mg/cm^2/day were recorded by treatment T9 at 60days. In *Summer* 2023 the net assimilation ratio at 30 DAS was maximum 7.15 mg/cm^2/day were recorded by treatment T9 and 1.10 mg/cm^2/day at 60 days were recorded by treatment T4, T5, T6 in mung bean respectively. In *Kharif* 2023, at 30 days maximum net assimilation ratio was 7.30 mg/cm^2/day and 1.12 mg/cm^2/day were recorded by treatment T9 at 60 days.
- In *Summer* 2022, the application phytohormone priming and foliar application of micro-nutrients in treatment (T9) increased the percentage in chlorophyll a by 43 and 34.3% at 30-days and 60-DAS as compared to treatment T0 (control). In *Kharif* 2022, combined foliar micronutrient application with SA priming in treatment (T10) increased the percentage in chlorophyll a by 35.6 at 30 DAS and 19.6% at 60 DAS when compared to the treatment (T0) control. In *Summer* 2023, the foliar application of Zinc and boron with priming of gibberellic acid i.e. (T9) increased the percentage in chlorophyll a by 49.7 and 21.2% at 30-days and 60-DAS in mung bean when compared to treatment T0 (control). In *Kharif* 2023, treatment (T10)

increased the percentage in chlorophyll a by 3 and 21.1% at 30-days and 60-DAS when compared to the control.

- In *Summer* 2022, the application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage in chlorophyll b by 34 and 25.4% at 30-days and 60-DAS as compared to treatment T0 (control). In *Kharif* 2022, combined foliar micronutrient application with SA priming in treatment (T10) increased the percentage in chlorophyll b by 27% at 30 DAS and 27.7% at 60 DAS when compared to the treatment (T0) control. In *Summer* 2023 mung bean, the foliar application of Zinc and boron with priming of gibberellic acid i.e. (T9) increased the percentage in chlorophyll b by 48 and 41% at 30-days and 60-DAS when compared to treatment T0 (control). In *Kharif* 2023, treatment (T10) increased the percentage in chlorophyll b by 3.9 and 44.3% at 30-days and 60-DAS when compared to the control.
- In *Summer* 2022, the application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage in chlorophyll a ratio b by 13.7 and 11.7% at 30-days and 60-DAS as compared to treatment T0 (control). In *Kharif* 2022, combined foliar micronutrient application with SA priming in treatment (T10) increased the percentage in chlorophyll a ratio b by 11.4 at 30 DAS and decreased by 10.8% at 60 DAS when compared to treatment T0 (control). In *Summer* 2023, the foliar application of Zinc and boron with priming of gibberellic acid i.e. (T9) decreased the percentage in chlorophyll a ratio b by 1.4 at 30 DAS and increased by 20.7% at 60 DAS in mung bean when compared to treatment T0 (control). In *Kharif* 2023, treatment (T10) increased the percentage in chlorophyll a ratio b by 3 and 28.2% at 30-days and 60-DAS when compared to the control.
- In *Summer* 2022, the application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage in chlorophyll index by 25.1 and 27.5% at 30-days and 60-DAS as compared to treatment T0 (control). In *Kharif* 2022, combined foliar micronutrient application with SA priming in treatment (T10) increased the percentage in chlorophyll index by 25.6 % at 30 DAS and 26.9% at 60 DAS when compared to the treatment (T0) control. In *Summer* 2023 mung bean crop, the foliar application of Zinc and boron with priming of gibberellic acid i.e. (T9) increased the percentage in chlorophyll index by 26.7 and 26.1% at 30-days and 60-DAS when compared to treatment T0 (control). In

Kharif 2023, treatment (T10) increased the percentage in chlorophyll index by 3 and 23.4% at 30-days and 60-DAS when compared to the control.

- In *Summer* 2022, the application phytohormone priming and foliar application of micronutrients in treatment (T9) increased the percentage in total soluble sugar by 35.2 and 41% at 30-days and 60-DAS as compared to treatment T0 (control). In *Kharif* 2022, combined foliar micronutrient application with SA priming in treatment (T10) increased the percentage in total soluble sugar by 29.6 % at 30 DAS and 35.8% at 60 DAS when compared to treatment T0 (control). In *Summer* 2023, the foliar application of Zinc and boron with priming of gibberellic acid i.e. (T9) increased the percentage in total soluble sugar by 35 and 42.3% at 30-days and 60-DAS in mung bean when compared to treatment T0 (control). In *Kharif* 2023, treatment (T10) increased the percentage in total soluble sugar by 32.8 and 30% at 30-days and 60-DAS when compared to the control.
- In *Summer* 2022, the percentage of total soluble protein (microgram/ml) was increased in T9 by 6.9% and 9.5% at 30-days and 60-DAS in mung bean respectively as compared to the control T0. In *Kharif* 2022 the percentage of total soluble protein (microgram/ml) was significantly increased in treatment T10 (i.e. combined foliar application of Zinc and boron in salicylic acid primed seed plants) 6.3% at 30 DAS and 8.1% at 60 DAS respectively as compared to control (T0). . In *Summer* 2023 the percentage of total soluble protein (microgram/ml) was significantly increased in treatment T9 (i.e. combined foliar application of Zinc and boron in gibberellin primed seed plants) 7.1% and 10.2% at 30-days and 60-DAS respectively as compared to control (T0).
- In *Summer* 2022 and 2023, the application gibberellic acid priming and foliar application of micronutrients in treatment (T9) increased the percentage in membrane stability index (%) by 12.9% and 14.9% in 2022 and 14.3%, 16.2% in 2023 at 30-days and 60-DAS as compared to treatment T0 (control). In *Kharif* 2022 and 2023, treatment (T10) increased the percentage in membrane stability index (%) by 16.2, 14.6% in 2022 and 18% at 30 DAS and 15.4% at 60 DAS in mung bean when compared to the treatment (T0) control.
- Among the applied phytohormones priming and foliar application of micronutrients, T10 decreases the membrane injury index (%) the percentage of membrane injury index by 54.3% and 54.6% at 30-days and 60-DAS when compared to the control (A0). In *Kharif* 2022 and

2023 Treatment T10 decreases the membrane injury index by 57.6% and 54.4% at 30-days and 60-DAS.

- In 2022 mung bean the foliar application of micronutrients and priming with gibberellic acid (T9) showed a better result by increasing number of pods/plant by 25.4% compared to the treatment (T0) control. The foliar application of zinc in T3 increases the number of pods/plant by 13.4% compared to the control. In 2023 Treatment (T9) enhances the pods/plant by 27.6% compared to control.
- Among the phytohormones, in *Summer* 2022 the seed priming with GA and zinc foliar application (T5) increased the percentage of number of seeds/pod by 8.8% compared to treatment T0 (control). In *Kharif* 2023 phytohormone priming (T9) and combined micronutrient foliar application increases seeds/pod by 17.8% compared to control (T0).
- The gibberellic acid and zinc foliar application (T5) in *Summer* 2023 mung bean showed a better result by increasing the pod length the rate by 11.5% compared to the control (A0). In *Summer* 2023 pod length increased by 23.4% when compared to control.
- The application of phytohormone priming and foliar application with Zn + B (T9) in *Summer* 2022 mung bean enhances the percentage of test weight by 10.4% when compared to control and in *Summer* 2023 in (T9) it enhanced by the percentage of test weight by 10.6% when compared to control (T0).
- The application of GA priming with combined micronutrient foliar application of zinc and boron treatment (T9) in *Summer* 2022 increases the percentage of seed yield by 22.8% when compared to control. In *Kharif* 2023 treatment (T9) seed yield in percentage increases by 22.6% compared to control (T0).
- The application of phytohormone priming i.e. GA with micronutrient foliar application (Zn+B) treatment (T9) in *Summer* 2022 mung bean increases the percentage of harvest index by 11.2% when compared to control. In *Kharif* 2023 harvest index in treatment (T9) increases by 10.5% compared to control (T0).
- The benefit cost ratio was found high in application of gibberellic acid (GA) priming with foliar application of zinc and boron by 2.06 in *Summer* 2022 and 1.82 in *Kharif* 2023 by salicylic acid (SA) seed priming with (Zn+B) foliar application in mung bean respectively.

- Among the phytohormones, in *Summer* 2022 the seed priming with GA and zinc foliar application in mung bean i.e. treatment (T9) increased the percentage of seed protein by 15.7% compared to treatment T0 (control). In *Kharif* 2023 phytohormone priming (T9) and combined micronutrient foliar application increases seed protein by 15.9% compared to control (T0).
- In *Summer* 2022 mung bean crop, it was recorded that the maximum amino acid (arginine) was found in T9 (0.68) followed by T10 (0.63%). In *Kharif* 2022, it was recorded that the maximum amino acid (arginine) was found in T9 (0.46%).

In summary, this study affirms that seed priming with gibberellic acid (GA) or salicylic acid (SA), when integrated with foliar application of zinc (Zn) and boron (B), is a scientifically robust and economically promising approach to enhancing mung bean productivity. The research, conducted from the perspective of an agronomist and rooted in field-level applicability, emphasizes significant improvements in key yield attributes such as pods per plant, seeds per pod, test weight, and overall seed yield. These physiological and morphological advancements directly contributed to increased net returns and a favorable benefit-cost ratio, underscoring the economic viability of the treatment combinations. The findings are highly relevant for extension personnel and development planners, as they provide a scalable strategy to bridge the persistent yield gap in pulse production. Furthermore, the adoption of such integrated practices can empower farmers particularly those operating under resource-constrained or rainfed conditions by improving productivity while maintaining input efficiency. The promotion of these results through demonstrations and on-farm participatory trials can accelerate technology transfer, contributing meaningfully to national goals of nutritional security, rural livelihood improvement, and sustainable, climate-resilient pulse-based farming systems.

Conclusion

The field investigation conducted over two consecutive years (2022 and 2023) during both the *Summer* and *Kharif* seasons has convincingly demonstrated the agronomic significance of integrating seed priming with phytohormones and the foliar application of essential micronutrients in mung bean (*Vigna radiata L.*). The experimental outcomes affirm that the strategic use of gibberellic acid (GA) and salicylic acid (SA) as seed priming agents, in conjunction with zinc (Zn) and boron (B) foliar sprays, profoundly influences the physiological, morphological, biochemical, and yield-related parameters of mung bean across both seasons and cultivars studied (SML1827 and ML1808). The treatments incorporating GA and SA priming markedly improved early-stage plant vigour, resulting in better germination, robust seedling emergence, and healthy crop establishment. These physiological advantages translated into notable enhancements in vegetative growth, including increases in plant height, branch formation, leaf proliferation, root development, and nodule formation. Improvements in root traits, particularly in root length and nodulation, also contributed to superior nutrient uptake efficiency and symbiotic nitrogen fixation, both of which are critical under sub-optimal soil fertility conditions. Biochemical traits such as chlorophyll content, membrane stability, and osmoprotectant accumulation were also positively influenced by the combined application of phytohormones and micronutrients. Treatments with integrated seed priming and foliar nutrient sprays maintained better photosynthetic activity, lower membrane injury under stress, and enhanced metabolic functions. This physiological robustness laid the foundation for improved flowering synchrony, efficient reproductive development, and superior translocation of assimilates toward economic yield formation. The effects of these agronomic interventions were consistently reflected in the yield-attributing parameters. Treatments integrating GA or SA with Zn and B resulted in increased pod development, seed size and weight, and ultimately higher grain yield. These improvements were consistent across both *Summer* and *Kharif* seasons, affirming the resilience and stability of the response across varying environmental conditions. Notably, treatments that combined GA priming with zinc and boron application outperformed other combinations in terms of both yield potential and harvest index, indicating superior efficiency in biomass partitioning toward the economic product. From an economic standpoint, the integrated use of phytohormone priming and micronutrient application notably enhanced the cost-effectiveness of mung bean cultivation. Treatments that led to higher productivity also yielded a more favourable benefit-cost ratio, ensuring that the improved agronomic performance translated into tangible economic gains for the farmers. These findings underscore the dual agronomic and economic value of adopting such input strategies, particularly in regions where pulses are a primary protein source and where productivity constraints have historically limited farmer income.

CHAPTER VI

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ANOVA tables for morphological parameters:-

1. ANOVA tables for germination percentage *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.515			
Treatment	10	32.667	3.267	3.411	0.009
Error	20	19.152	0.958		
Total	32	53.333			
CD	1.67		**CV**	7.93	

Germination percentage *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.727			
Treatment	10	32.848	3.285	4.498	0.002
Error	20	14.606	0.730		
Total	32	48.182			
CD	1.46		**CV**	6.86	

Germination percentage *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.424			
Treatment	10	18.727	1.873	2.901	0.020
Error	20	12.909	0.645		
Total	32	32.061			
CD	1.37	**CV**	9.17		

Germination percentage *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.242			
Treatment	10	7.333	0.733	1.891	0.108
Error	20	7.758	0.388		
Total	32	15.333			
CD	1.06		**CV**	7.19	

2. ANOVA tables for 30DAS plant Height *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.197			
Treatment	10	107.136	10.714	18.414	< 0.001
Error	20	11.636	0.582		
Total	32	123.970			
CD	1.30		**CV**	5.73	

30 DAS plant height *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.669			
Treatment	10	60.929	6.093	6.145	< 0.001
Error	20	19.832	0.992		
Total	32	83.429			
CD	1.70		**CV**	8.38	

30 DAS plant height *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.563			
Treatment	10	46.896	4.690	4.243	0.003
Error	20	22.104	1.105		
Total	32	70.563			
CD	1.80		**CV**	7.99	

30 DAS plant height *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.742			
Treatment	10	100.045	10.005	15.285	< 0.001
Error	20	13.091	0.655		
Total	32	116.879			
CD	1.38		**CV**	0.46	

60 DAS plant height *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	20.470			
Treatment	10	170.061	17.006	4.048	0.004
Error	20	84.030	4.202		
Total	32	274.561			
CD	3.51		**CV**	3.49	

60 DAS Plant Height *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	8.665			
Treatment	10	256.960	25.696	3.250	0.012
Error	20	158.127	7.906		
Total	32	423.753			
CD	4.82		**CV**	5.13	

60 DAS plant height *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	19.909			
Treatment	10	212.592	21.259	2.692	0.028
Error	20	157.951	7.898		
Total	32	390.452			
CD	4.82		**CV**	4.98	

60 DAS plant height *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.432			
Treatment	10	402.340	40.234	9.393	< 0.001
Error	20	85.665	4.283		
Total	32	491.437			
CD	3.55		**CV**	3.78	

At harvest plant height *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	30.655			
Treatment	10	348.921	34.892	8.766	< 0.001
Error	20	79.604	3.980		
Total	32	459.181			
CD	3.42		**CV**	3.21	

At harvest plant height *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	107.546			
Treatment	10	249.524	24.952	7.386	< 0.001
Error	20	67.565	3.378		
Total	32	424.635			
CD	3.15		**CV**	3.11	

At harvest plant height *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	122.390			
Treatment	10	397.479	39.748	11.422	< 0.001
Error	20	69.600	3.480		
Total	32	589.469			
CD	3.20		**CV**	3.05	

At harvest plant height *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	14.672			
Treatment	10	331.696	33.170	8.714	< 0.001
Error	20	76.133	3.807		
Total	32	422.500			
CD	3.34		**CV**	3.22	

3. ANOVA table for 30 DAS number of leaves *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	53.924			
Treatment	10	142.379	14.238	6.535	< 0.001
Error	20	43.576	2.179		
Total	32	239.879			
CD	2.53		**CV**	7.42	

30 DAS number of leaves *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.719			
Treatment	10	105.734	10.573	7.721	< 0.001
Error	20	27.387	1.369		
Total	32	133.840			
CD	2.00		**CV**	7.67	

30 DAS number of leaves *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.545			
Treatment	10	106.242	10.624	8.809	< 0.001
Error	20	24.121	1.206		
Total	32	130.909			
CD	1.88		**CV**	6.53	

30 DAS number of leaves *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	10.364			
Treatment	10	156.242	15.624	9.674	< 0.001
Error	20	32.303	1.615		
Total	32	198.909			
CD	2.18		**CV**	8.57	

60 DAS number of leaves *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	134.206			
Treatment	10	267.491	26.749	2.996	0.018
Error	20	178.554	8.928		
Total	32	580.251			
CD	5.12		**CV**	8.30	

60 DAS number of leaves *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	12.487			
Treatment	10	274.380	27.438	5.365	0.001
Error	20	102.288	5.114		
Total	32	389.154			
CD	3.87		**CV**	6.91	

60 DAS number of leaves *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.629			
Treatment	10	373.093	37.309	11.189	< 0.001
Error	20	66.692	3.335		
Total	32	443.414			
CD	3.13		**CV**	5.38	

60 DAS number of leaves *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.037			
Treatment	10	375.544	37.554	13.901	< 0.001
Error	20	54.030	2.701		
Total	32	431.611			
CD	2.81		**CV**	4.99	

4. ANOVA table for 30 DAS number of branches *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.045			
Treatment	10	7.409	0.741	6.037	< 0.001
Error	20	2.455	0.123		
Total	32	9.909			
CD	0.60		**CV**	10.55	

30 DAS number of branches *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.004			
Treatment	10	10.896	1.090	53.280	< 0.001
Error	20	0.409	0.020		
Total	32	11.310			
CD	0.24		**CV**	5.49	

30 DAS number of branches *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.136			
Treatment	10	10.727	1.073	15.733	< 0.001
Error	20	1.364	0.068		
Total	32	12.227			
CD	0.44		**CV**	8.97	

30 DAS number of branches *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.061			
Treatment	10	7.333	0.733	15.613	< 0.001
Error	20	0.939	0.047		
Total	32	8.333			
CD	0.37		**CV**	9.28	

60 DAS number of branches *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.106			
Treatment	10	20.182	2.018	9.548	< 0.001
Error	20	4.227	0.211		
Total	32	24.515			
CD	0.78		**CV**	9.42	

60 DAS number of branches *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.045			
Treatment	10	17.076	1.708	19.102	< 0.001
Error	20	1.788	0.089		
Total	32	18.909			
CD	0.51		**CV**	6.20	

60 DAS number of branches *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.045			
Treatment	10	13.136	1.314	5.898	< 0.001
Error	20	4.455	0.223		
Total	32	17.636			
CD	0.80		**CV**	10.81	

60 DAS number of branches *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.099			
Treatment	10	20.276	2.028	21.481	< 0.001
Error	20	1.888	0.094		
Total	32	22.262			
CD	0.52		**CV**	6.75	

5. ANOVA table for 30 DAS number of nodules *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	28.364			
Treatment	10	552.242	55.224	21.957	< 0.001
Error	20	50.303	2.515		
Total	32	630.909			
CD	2.72		**CV**	6.65	

30 DAS number of nodules *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	28.424			
Treatment	10	653.212	65.321	19.722	< 0.001
Error	20	66.242	3.312		
Total	32	747.879			
CD	3.12		**CV**	10.07	

30 DAS number of nodules *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	39.327			
Treatment	10	572.563	57.256	20.768	< 0.001
Error	20	55.139	2.757		
Total	32	667.029			
CD	2.84		**CV**	8.15	

30 DAS number of nodules *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	41.295			
Treatment	10	709.739	70.974	32.097	< 0.001
Error	20	44.225	2.211		
Total	32	795.259			
CD	2.55		**CV**	9.66	

60 DAS number of nodules *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.818			
Treatment	10	950.959	95.096	9.887	< 0.001
Error	20	192.368	9.618		
Total	32	1,147.145			
CD	5.31		**CV**	8.67	

60 DAS number of nodules *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	12.362			
Treatment	10	886.158	88.616	8.303	< 0.001
Error	20	213.459	10.673		
Total	32	1,111.979			
CD	5.60		**CV**	10.90	

60 DAS number of nodules *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	18.495			
Treatment	10	891.846	89.185	13.388	Treatment
Error	20	133.226	6.661		Error
Total	32	1,043.567			
CD	4.42		**CV**	8.20	

60 DAS number of nodules *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.275			
Treatment	10	1,089.841	108.984	12.803	< 0.001
Error	20	170.252	8.513		
Total	32	1,264.369			
CD	5.00		**CV**	10.96	

6. ANOVA table for 30 DAS root length *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	11.756			
Treatment	10	170.061	17.006	4.938	0.001
Error	20	68.884	3.444		
Total	32	250.702			
CD	3.18		**CV**	9.79	

30 DAS root lenght *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.164			
Treatment	10	216.976	21.698	14.656	< 0.001
Error	20	29.609	1.480		
Total	32	248.750			
CD	2.08		**CV**	8.22	

30 DAS root length *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.515			
Treatment	10	206.227	20.623	12.379	< 0.001
Error	20	33.318	1.666		
Total	32	245.061			
CD	2.21		**CV**	7.78	

30 DAS root lenght *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	9.561			
Treatment	10	120.015	12.002	7.399	< 0.001
Error	20	32.439	1.622		
Total	32	162.015			
CD	2.18		**CV**	10.50	

60 DAS root length *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	13.682			
Treatment	10	364.015	36.402	7.705	< 0.001
Error	20	94.485	4.724		
Total	32	472.182			
CD	3.72		**CV**	8.34	

60 DAS root lenght *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.015			
Treatment	10	274.136	27.414	5.411	0.001
Error	20	101.318	5.066		
Total	32	378.470			
CD	3.86		**CV**	9.87	

60 DAS root length *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	49.106			
Treatment	10	275.909	27.591	4.810	0.001
Error	20	114.727	5.736		
Total	32	439.742			
CD	4.10		**CV**	9.97	

60 DAS root lenght *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.006			
Treatment	10	274.131	27.413	5.411	0.001
Error	20	101.326	5.066		
Total	32	378.464			
CD	3.86		**CV**	10.97	

7. ANOVA table for 30 DAS fresh weight *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.289			
Treatment	10	435.487	43.549	8.095	< 0.001
Error	20	107.599	5.380		
Total	32	544.375			
CD	3.97		**CV**	13.85	

30 DAS fresh weight *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	6.358			
Treatment	10	117.940	11.794	6.308	< 0.001
Error	20	37.393	1.870		
Total	32	161.691			
CD	2.34		**CV**	9.78	

30 DAS fresh weight *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.291			
Treatment	10	435.489	43.549	8.095	< 0.001
Error	20	107.597	5.380		
Total	32	544.377			
CD	3.97		**CV**	12.64	

30 DAS fresh weight *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	16.044			
Treatment	10	195.965	19.596	18.083	< 0.001
Error	20	21.674	1.084		
Total	32	233.683			
CD	1.78		**CV**	9.91	

60 DAS fresh weight *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	77.739			
Treatment	10	4,780.834	478.083	31.881	< 0.001
Error	20	299.916	14.996		
Total	32	5,158.488			
CD	6.64		**CV**	3.84	

60 DAS fresh weight *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	286.725			
Treatment	10	4,064.005	406.401	18.657	< 0.001
Error	20	435.658	21.783		
Replication	2	286.725			
CD	8.00		**CV**	4.99	

60 DAS fresh weight *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	551.733			
Treatment	10	4,064.090	406.409	11.452	< 0.001
Error	20	709.791	35.490		
Total	32	5,325.614			
CD	10.21		**CV**	7.03	

60 DAS fresh weight *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	26.131			
Treatment	10	7,132.107	713.211	40.280	< 0.001
Error	20	354.128	17.706		
Total	32	7,512.367			
CD	7.21		**CV**	4.98	

At harvest fresh weight *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	88.044			
Treatment	10	6,466.142	646.614	10.983	< 0.001
Error	20	1,177.457	58.873		
Total	32	7,731.644			
CD	13.16		**CV**	6.76	

At harvest fresh weight *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	37.933			
Treatment	10	6,355.164	635.516	37.746	< 0.001
Error	20	336.729	16.836		
Total	32	6,729.825			
CD	7.03		**CV**	3.63	

At harvest fresh weight *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	6.269			
Treatment	10	6,075.317	607.532	15.045	< 0.001
Error	20	807.597	40.380		
Total	32	6,889.184			
CD	10.89		**CV**	5.88	

At harvest fresh weight *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	25.680			
Treatment	10	7,027.133	702.713	40.612	< 0.001
Error	20	346.061	17.303		
Total	32	7,398.874			
CD	7.13		**CV**	4.21	

8. ANOVA table for 30 DAS dry weight *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.573			
Treatment	10	22.342	2.234	4.151	0.003
Error	20	10.765	0.538		
Total	32	33.680			
CD	1.25		**CV**	12.11	

30 DAS dry weight *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.553			
Treatment	10	10.230	1.023	6.403	< 0.001
Error	20	3.195	0.160		
Total	32	13.979			
CD	0.68		**CV**	9.72	

30 DAS dry weight *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.525			
Treatment	10	9.483	0.948	9.083	< 0.001
Error	20	2.088	0.104		
Total	32	12.097			
CD	0.55		**CV**	7.37	

30 DAS dry weight *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.481			
Treatment	10	21.084	2.108	21.402	< 0.001
Error	20	1.970	0.099		
Total	32	24.536			
CD	0.53		**CV**	9.01	

60 DAS dry weight *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.105			
Treatment	10	1,042.185	104.218	103.106	< 0.001
Error	20	20.216	1.011		
Total	32	1,066.506			
CD	1.72		**CV**	3.68	

60 DAS dry weight *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.731			
Treatment	10	285.267	28.527	31.214	< 0.001
Error	20	18.278	0.914		
Total	32	307.275			
CD	1.64		**CV**	3.76	

60 DAS dry weight *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.434			
Treatment	10	340.461	34.046	43.076	< 0.001
Error	20	15.808	0.790		
Total	32	356.704			
CD	1.52		**CV**	3.55	

60 DAS dry weight *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.103			
Treatment	10	565.582	56.558	70.026	< 0.001
Error	20	16.153	0.808		
Total	32	585.838			
CD	1.54		**CV**	3.83	

At harvest dry weight *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.225			
Treatment	10	1,122.970	112.297	103.535	< 0.001
Error	20	21.692	1.085		
Total	32	1,145.888			
CD	1.78		**CV**	2.94	

At harvest dry weight *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	7.460			
Treatment	10	590.728	59.073	108.541	< 0.001
Error	20	10.885	0.544		
Total	32	609.072			
CD	1.26		**CV**	2.22	

At harvest dry weight *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.425			
Treatment	10	479.683	47.968	46.593	< 0.001
Error	20	20.590	1.030		
Total	32	501.698			
CD	1.74		**CV**	3.21	

At harvest dry weight *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.442			
Treatment	10	545.990	54.599	47.778	< 0.001
Error	20	22.855	1.143		
Total	32	569.287			
CD	1.83		**CV**	3.83	

9. ANOVA table for 30 DAS leaf area *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	68.805			
Treatment	10	2,910.219	291.022	18.848	< 0.001
Error	20	308.803	15.440		
Total	32	3,287.828			
CD	6.74		**CV**	3.79	

30 DAS leaf area *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	128.200			
Treatment	10	2,884.102	288.410	51.711	< 0.001
Error	20	111.547	5.577		
Total	32	3,123.849			
CD	4.05		**CV**	2.47	

30 DAS leaf area *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	67.593			
Treatment	10	3,120.158	312.016	17.533	< 0.001
Error	20	355.921	17.796		
Total	32	3,543.671			
CD	7.23		**CV**	4.26	

30 DAS leaf area *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	126.264			
Treatment	10	3,170.936	317.094	51.919	< 0.001
Error	20	122.150	6.108		
Total	32	3,419.350			
CD	4.23		**CV**	2.75	

60 DAS leaf area *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	6,616.626			
Treatment	10	2,029,830.270	202,983.027	11.540	< 0.001
Error	20	351,790.810	17,589.541		
Total	32	2,388,237.706			
CD	227.4		**CV**	5.48	

60 DAS leaf area *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	6,402.779			
Treatment	10	1,920,672.180	192,067.218	9.195	< 0.001
Error	20	417,757.085	20,887.854		
Total	32	2,344,832.043			
CD	247.8		**CV**	6.80	

60 DAS leaf area *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	7,916.317			
Treatment	10	1,990,145.014	199,014.501	9.011	< 0.001
Error	20	441,728.107	22,086.405		
Total	32	2,439,789.438			
CD	254.9		**CV**	6.841	

60 DAS leaf area *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	79,002.441			
Treatment	10	3,201,698.521	320,169.852	31.607	< 0.001
Error	20	202,595.344	10,129.767		
Total	32	3,483,296.306			
CD	172.6		**CV**	4.96	

10. ANOVA table for days to 50% flowering *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.970			
Treatment	10	76.061	7.606	10.121	< 0.001
Error	20	15.030	0.752		
Total	32	94.061			
CD	1.48		**CV**	2.23	

Days to 50% flowering *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.788			
Treatment	10	54.970	5.497	8.321	< 0.001
Error	20	13.212	0.661		
Total	32	68.970			
CD	1.39		**CV**	2.03	

Days to 50% flowering *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.182			
Treatment	10	59.333	5.933	9.505	< 0.001
Error	20	12.485	0.624		
Total	32	72.000			
CD	1.35		**CV**	1.97	

Days to 50% flowering *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.242			
Treatment	10	46.303	4.630	7.454	< 0.001
Error	20	12.424	0.621		
Total	32	58.970			
CD	1.35		**CV**	1.92	

B. ANOVA tables for biochemical parameters:-

1. ANOVA table for Chlorophyll a *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.015			
Treatment	10	2.904	0.290	143.410	< 0.001
Error	20	0.040	0.002		
Total	32	2.959			
CD	007		**CV**	2.69	

30 DAS chlorophyll a *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.004			
Treatment	10	1.712	0.171	74.716	< 0.001
Error	20	0.046	0.002		
Total	32	1.761			
CD	0.08		**CV**	4.59	

30 DAS chlorophyll a *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.000			
Treatment	10	1.005	0.100	109.924	< 0.001
Error	20	0.018	0.001		
Total	32	1.024			
CD	0.05		**CV**	2.66	

30 DAS chlorophyll a *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.004			
Treatment	10	1.457	0.146	100.609	< 0.001
Error	20	0.029	0.001		
Total	32	1.490			
CD	0.06		**CV**	3.87	

60 DAS chlorophyll a *Summer* 2022

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.046			
Treatment	10	8.755	0.876	157.807	
Error	20	0.111	0.006		
Total	32	8.912			
CD	0.12		**CV**	1.88	

60 DAS chlorophyll a *Summer* 2023

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.007			
Treatment	10	3.733	0.373	52.905	< 0.001
Error	20	0.141	0.007		
Total	32	3.882			
CD	0.14		**CV**	2.13	

60 DAS chlorophyll a *Kharif* 2022

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.029			
Treatment	10	3.202	0.320	117.957	< 0.001
Error	20	0.054	0.003		
Total	32	3.284			
CD	0.08		**CV**	1.26	

60 DAS chlorophyll a *Kharif* 2023

Source of Variation	**DF**	**Sum of Squares**	**Mean Squares**	**F-Calculated**	**Significance**
Replication	2	0.015			
Treatment	10	3.197	0.320	76.573	< 0.001
Error	20	0.084	0.004		
Total	32	3.296			
CD	0.11		**CV**	1.77	

2. ANOVA table for Chlorophyll b *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.020			
Treatment	10	0.995	0.100	27.201	< 0.001
Error	20	0.073	0.004		
Total	32	1.088			
CD	0.10		**CV**	4.11	

30 DAS chlorophyll b *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.019			
Treatment	10	1.361	0.136	41.527	< 0.001
Error	20	0.066	0.003		
Total	32	1.446			
CD	0.09		**CV**	5.25	

30 DAS chlorophyll b *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.039			
Treatment	10	1.379	0.138	43.928	< 0.001
Error	20	0.063	0.003		
Total	32	1.481			
CD	0.09		**CV**	4.17	

30 DAS chlorophyll b *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.011			
Treatment	10	1.315	0.131	25.015	< 0.001
Error	20	0.105	0.005		
Total	32	1.431			
CD	0.12		**CV**	9.32	

60 DAS chlorophyll b *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.032			
Treatment	10	1.697	0.170	22.644	< 0.001
Error	20	0.150	0.007		
Total	32	1.880			
CD	0.14		**CV**	3.23	

60 DAS chlorophyll b *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.031			
Treatment	10	1.423	0.142	14.303	< 0.001
Error	20	0.199	0.010		
Total	32	1.653			
CD	0.17		**CV**	7.68	

60 DAS chlorophyll b *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.042			
Treatment	10	1.293	0.129	16.011	< 0.001
Error	20	0.162	0.008		
Total	32	1.497			
CD	0.15		**CV**	5.07	

60 DAS chlorophyll b *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.017			
Treatment	10	1.167	0.117	11.053	< 0.001
Error	20	0.211	0.011		
Total	32	1.395			
CD	0.17		**CV**	9.61	

3. ANOVA table for Chlorophyll a/b *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.002			
Treatment	10	0.219	0.022	5.592	0.001
Error	20	0.078	0.004		
Total	32	0.299			
CD	0.10		**CV**	5.53	

30 DAS chlorophyll a/b *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.014			
Treatment	10	0.113	0.011	1.816	0.123
Error	20	0.125	0.006		
Total	32	0.253			
CD	0.13		**CV**	12.08	

30 DAS chlorophyll a/b *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.016			
Treatment	10	0.108	0.011	6.343	< 0.001
Error	20	0.034	0.002		
Total	32	0.158			
CD	0.07		**CV**	4.87	

30 DAS chlorophyll a/b *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.022			
Treatment	10	0.666	0.067	2.739	0.026
Error	20	0.486	0.024		
Total	32	1.174			
CD	0.26		**CV**	12.04	

60 DAS chlorophyll a/b *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.002			
Treatment	10	0.292	0.029	7.796	< 0.001
Error	20	0.075	0.004		
Total	32	0.369			
CD	0.10		**CV**	4.16	

60 DAS chlorophyll a/b *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.239			
Treatment	10	2.184	0.218	2.731	0.027
Error	20	1.600	0.080		
Total	32	4.023			
CD	0.48		**CV**	9.17	

60 DAS chlorophyll a/b *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.071			
Treatment	10	0.401	0.040	2.040	0.084
Error	20	0.393	0.020		
Total	32	0.866			
CD	0.24		**CV**	5.98	

60 DAS chlorophyll a/b *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.008			
Treatment	10	7.715	0.772	15.500	< 0.001
Error	20	0.996	0.050		
Total	32	8.719			
CD	0.38		**CV**	6.34	

4. ANOVA table for 30 DAS total soluble protein *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.340			
Treatment	10	6.457	0.646	8.547	< 0.001
Error	20	1.511	0.076		
Total	32	11.308			
CD	0.47		**CV**	1.44	

30 DAS total soluble protein *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.633			
Treatment	10	6.348	0.635	41.551	< 0.001
Error	20	0.306	0.015		
Total	32	8.287			
CD	0.21		**CV**	0.68	

30 DAS total soluble protein *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.184			
Treatment	10	6.646	0.665	10.152	< 0.001
Error	20	1.309	0.065		
Total	32	8.139			
CD	0.43		**CV**	1.41	

30 DAS total soluble protein *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.176			
Treatment	10	6.073	0.607	18.001	< 0.001
Error	20	0.675	0.034		
Total	32	6.924			
CD	0.31		**CV**	1.05	

60 DAS total soluble protein *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	5.136			
Treatment	10	6.744	0.674	9.648	< 0.001
Error	20	1.398	0.070		
Total	32	13.279			
CD	0.45		**CV**	2.04	

60 DAS total soluble protein *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.572			
Treatment	10	6.633	0.663	9.609	< 0.001
Error	20	1.380	0.069		
Total	32	8.585			
CD	0.45		**CV**	2.20	

60 DAS total soluble protein *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.374			
Treatment	10	6.634	0.663	9.623	< 0.001
Error	20	1.379	0.069		
Total	32	8.388			
CD	0.45		**CV**	2.18	

60 DAS total soluble protein *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.038			
Treatment	10	6.487	0.649	8.700	< 0.001
Error	20	1.491	0.075		
Total	32	8.016			
CD	0.46		**CV**	2.42	

5. ANOVA table for 30 DAS total soluble sugar *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.018			
Treatment	10	0.988	0.099	23.578	< 0.001
Error	20	0.084	0.004		
Total	32	1.090			
CD	0.11		**CV**	5.23	

30 DAS total soluble sugar *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.015			
Treatment	10	0.950	0.095	6.543	< 0.001
Error	20	0.290	0.015		
Total	32	1.255			
CD	0.27		**CV**	10.43	

30 DAS total soluble sugar *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.007			
Treatment	10	0.985	0.099	21.708	< 0.001
Error	20	0.091	0.005		
Total	32	1.083			
CD	0.11		**CV**	5.87	

30 DAS total soluble sugar *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.007			
Treatment	10	1.091	0.109	16.222	< 0.001
Error	20	0.134	0.007		
Total	32	1.233			
CD	0.14		**CV**	7.59	

60 DAS total soluble sugar *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.051			
Treatment	10	2.817	0.282	39.352	< 0.001
Error	20	0.143	0.007		
Total	32	3.011			
CD	0.14		**CV**	4.53	

60 DAS total soluble sugar *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.043			
Treatment	10	2.687	0.269	44.880	< 0.001
Error	20	0.120	0.006		
Total	32	2.850			
CD	0.13		**CV**	4.38	

60 DAS total soluble sugar *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.038			
Treatment	10	2.190	0.219	27.852	< 0.001
Error	20	0.157	0.008		
Total	32	2.385			
CD	0.15		**CV**	4.98	

60 DAS total soluble sugar *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.042			
Treatment	10	2.276	0.228	23.473	< 0.001
Error	20	0.194	0.010		
Total	32	2.512			
CD	0.16		**CV**	5.83	

6. ANOVA table for 30 DAS membrane stability index *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	21.012			
Treatment	10	496.664	49.666	5.002	0.001
Error	20	198.593	9.930		
Total	32	716.269			
CD	5.40		**CV**	3.86	

30 DAS membrane stability index *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	78.480			
Treatment	10	562.630	56.263	4.990	0.001
Error	20	225.499	11.275		
Total	32	866.609			
CD	5.75		**CV**	4.21	

30 DAS membrane stability index *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	25.153			
Treatment	10	510.569	51.057	5.116	0.001
Error	20	199.586	9.979		
Total	32	735.308			
CD	5.41		**CV**	3.94	

30 DAS membrane stability index *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	90.525			
Treatment	10	646.732	64.673	4.994	0.001
Error	20	259.013	12.951		
Total	32	996.270			
CD	6.17		**CV**	4.50	

60 DAS membrane stability index *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	7.405			
Treatment	10	561.726	56.173	20.548	< 0.001
Error	20	54.674	2.734		
Total	32	623.804			
CD	2.83		**CV**	1.94	

60 DAS membrane stability index *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	21.223			
Treatment	10	612.746	61.275	16.725	< 0.001
Error	20	73.273	3.664		
Total	32	707.243			
CD	3.28		**CV**	2.33	

60 DAS membrane stability index *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	12.631			
Treatment	10	504.883	50.488	17.389	< 0.001
Error	20	58.070	2.904		
Total	32	575.584			
CD	2.92		**CV**	2.04	

60 DAS membrane stability index *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	19.436			
Treatment	10	579.609	57.961	16.750	< 0.001
Error	20	69.209	3.460		
Total	32	668.254			
CD	3.19		**CV**	2.25	

7. ANOVA table for 30 DAS membrane injury index *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	21.032			
Treatment	10	496.689	49.669	5.003	0.001
Error	20	198.565	9.928		
Total	32	716.286			
CD	5.40		**CV**	17.09	

30 DAS membrane injury index *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	78.510			
Treatment	10	562.638	56.264	4.991	0.001
Error	20	225.467	11.273		
Total	32	866.616			
CD	5.75		**CV**	16.53	

30 DAS membrane injury index *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	25.174			
Treatment	10	510.586	51.059	5.117	0.001
Error	20	199.571	9.979		
Total	32	735.331			
CD	5.41		**CV**	15.83	

30 DAS membrane injury index *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	90.468			
Treatment	10	646.674	64.667	4.992	0.001
Error	20	259.074	12.954		
Total	32	996.216			
CD	6.17		**CV**	17.94	

60 DAS membrane injury index *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	7.394			
Treatment	10	561.720	56.172	20.545	< 0.001
Error	20	54.682	2.734		
Total	32	623.796			
CD	2.83		**CV**	10.91	

60 DAS membrane injury index *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	21.121			
Treatment	10	612.632	61.263	16.697	< 0.001
Error	20	73.382	3.669		
Total	32	707.135			
CD	3.28		**CV**	10.56	

60 DAS membrane injury index *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	12.702			
Treatment	10	504.932	50.493	17.411	< 0.001
Error	20	58.000	2.900		
Total	32	575.634			
CD	2.92		**CV**	10.11	

60 DAS membrane injury index *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	19.437			
Treatment	10	579.600	57.960	16.748	< 0.001
Error	20	69.213	3.461		
Total	32	668.250			
CD	3.19		**CV**	10.53	

8. ANOVA table for 30 DAS chlorophyll index *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	151.758			
Treatment	10	519.121	51.912	5.982	< 0.001
Error	20	173.562	8.678		
Total	32	844.440			
CD	5.05		**CV**	6.37	

30 DAS chlorophyll index *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	24.533			
Treatment	10	520.522	52.052	9.982	< 0.001
Error	20	104.296	5.215		
Total	32	649.351			
CD	3.91		**CV**	5.47	

30 DAS chlorophyll index *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	101.256			
Treatment	10	519.114	51.911	10.690	< 0.001
Error	20	97.124	4.856		
Total	32	717.495			
CD	3.78		**CV**	4.85	

30 DAS chlorophyll index *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	131.745			
Treatment	10	493.167	49.317	11.443	< 0.001
Error	20	86.195	4.310		
Total	32	711.107			
CD	3.56		**CV**	5.15	

60 DAS chlorophyll index *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	8.804			
Treatment	10	773.208	77.321	7.687	< 0.001
Error	20	201.176	10.059		
Total	32	983.188			
CD	5.44		**CV**	5.98	

60 DAS chlorophyll index *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	7.321			
Treatment	10	660.748	66.075	10.068	< 0.001
Error	20	131.257	6.563		
Total	32	799.326			
CD	4.39		**CV**	5.39	

60 DAS chlorophyll index *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	6.495			
Treatment	10	773.165	77.316	10.789	< 0.001
Error	20	143.329	7.166		
Total	32	922.989			
CD	4.59		**CV**	5.13	

60 DAS chlorophyll index *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	124.102			
Treatment	10	661.077	66.108	22.118	< 0.001
Error	20	59.776	2.989		
Total	32	844.955			
CD	2.96		**CV**	3.72	

C. ANOVA tables for yield attributes:-

1. ANOVA table for number of pods per plant *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	52.788			
Treatment	10	431.879	43.188	9.470	< 0.001
Error	20	91.212	4.561		
Total	32	575.879			
CD	3.663		**CV**	5.629	

Number of pods per plant *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	42.723			
Treatment	10	382.012	38.201	8.608	Treatment
Error	20	88.761	4.438		Error
Total	32	513.496			
CD	3.613		**CV**	5.996	

Number of pods per plant *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	41.227			
Treatment	10	463.545	46.355	10.073	< 0.001
Error	20	92.040	4.602		
Total	32	596.813			
CD	3.679		**CV**	5.881	

Number of pods per plant *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	76.900			
Treatment	10	317.591	31.759	5.149	0.001
Error	20	123.360	6.168		
Total	32	517.851			
CD	4.260		**CV**	7.475	

2. ANOVA table for number of seeds per pod *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.652			
Treatment	10	7.515	0.752	2.195	0.065
Error	20	6.848	0.342		
Total	32	15.015			
CD	0.846		**CV**	5.262	

Number of seeds per pod *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.218			
Treatment	10	12.966	1.297	3.861	0.005
Error	20	6.716	0.336		
Total	32	20.901			
CD	0.994		**CV**	5.524	

Number of seeds per pod *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.095			
Treatment	10	9.018	0.902	3.723	0.006
Error	20	4.845	0.242		
Total	32	13.958			
CD	0.844		**CV**	4.84	

Number of seeds per pod *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	4.053			
Treatment	10	12.966	1.297	3.955	0.004
Error	20	6.557	0.328		
Total	32	23.576			
CD	0.982		**CV**	6.163	

3. ANOVA table for pod length *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.564			
Treatment	10	9.846	0.985	4.792	0.001
Error	20	4.109	0.205		
Total	32	14.519			
CD	0.777		**CV**	5.500	

Pod length *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.408			
Treatment	10	9.912	0.991	6.385	< 0.001
Error	20	3.105	0.155		
Total	32	14.425			
CD	0.662		**CV**	5.034	

Pod length *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.671			
Treatment	10	13.016	1.302	4.549	0.002
Error	20	5.722	0.286		
Total	32	19.410			
CD	0.917		**CV**	6.797	

Pod length *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.107			
Treatment	10	12.228	1.223	4.644	0.002
Error	20	5.266	0.263		
Total	32	19.601			
CD	0.880		**CV**	6.974	

4. ANOVA table for 1000 seeds weight *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	13.960			
Treatment	10	83.512	8.351	3.041	0.016
Error	20	54.920	2.746		
Total	32	152.392			
CD	2.842		**CV**	3.746	

1000 seeds weight *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	13.648			
Treatment	10	83.511	8.351	5.937	< 0.001
Error	20	28.131	1.407		
Total	32	125.290			
CD	2.034		**CV**	2.724	

1000 seeds weight *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	6.211			
Treatment	10	80.294	8.029	6.212	< 0.001
Error	20	25.851	1.293		
Total	32	112.356			
CD	1.950		**CV**	2.703	

1000 seeds weight *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	7.380			
Treatment	10	85.026	8.503	7.077	< 0.001
Error	20	24.028	1.201		
Total	32	116.435			
CD	1.880		**CV**	2.670	

5. ANOVA table for seeds yield *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	81.566			
Treatment	10	4,342.316	434.232	31.608	< 0.001
Error	20	274.761	13.738		
Total	32	4,698.642			
CD	6.35		**CV**	2.84	

Seeds yield *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	36.779			
Treatment	10	3,867.664	386.766	37.319	< 0.001
Error	20	207.273	10.364		
Total	32	4,111.717			
CD	5.52		**CV**	2.58	

Seeds yield *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	71.454			
Treatment	10	3,972.670	397.267	38.396	< 0.001
Error	20	206.931	10.347		
Total	32	4,251.054			
CD	5.51		**CV**	2.52	

Seeds yield *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	55.333			
Treatment	10	3,600.532	360.053	34.833	< 0.001
Error	20	206.728	10.336		
Total	32	3,862.594			
CD	5.51		**CV**	2.63	

6. ANOVA table for harvest index *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.482			
Treatment	10	32.901	3.290	7.583	< 0.001
Error	20	8.677	0.434		
Total	32	43.060			
CD	1.13		**CV**	2.79	

Harvest index *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.816			
Treatment	10	30.750	3.075	7.757	< 0.001
Error	20	7.928	0.396		
Total	32	39.494			
CD	1.08		**CV**	2.73	

Harvest index *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	3.249			
Treatment	10	30.470	3.047	6.766	< 0.001
Error	20	9.007	0.450		
Total	32	42.727			
CD	1.15		**CV**	2.89	

Harvest index *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	1.068			
Treatment	10	27.362	2.736	7.631	< 0.001
Error	20	7.171	0.359		
Total	32	35.601			
CD	1.02		**CV**	2.63	

7. ANOVA table for seed Protein *Summer* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	18.077			
Treatment	10	57.314	5.731	1.682	0.155
Error	20	68.163	3.408		
Total	32	143.553			
CD	3.14		**CV**	7.48	

Seed Protein *Summer* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	21.248			
Treatment	10	46.902	4.690	1.733	0.142
Error	20	54.133	2.707		
Total	32	122.283			
CD	2.81		**CV**	6.98	

Seed Protein *Kharif* 2022

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	22.376			
Treatment	10	56.181	5.618	1.877	0.111
Error	20	59.864	2.993		
Total	32	138.421			
CD	2.95		**CV**	7.11	

Seed Protein *Kharif* 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	25.624			
Treatment	10	52.256	5.226	2.090	0.077
Error	20	50.017	2.501		
Total	32	127.897			
CD	2.69		**CV**	6.73	