EFFECT OF DIFFERENT LEVELS OF SULPHUR AND ZINC ON GROWTH, YIELD AND QUALITY ATTRIBUTES OF GOBHI SARSON (*Brassica napus* L.)

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

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DECLARATION

I, hereby declared that the presented work in the thesis entitled "Effect of different levels of sulphur and zinc on growth, yield and quality attributes of gobhi sarson (*Brassica napus* L.)" in fulfillment of degree of **Doctor of Philosophy (Ph.D.)** is outcome of research work carried out by me under the supervision of Dr. Mayur S. Darvhankar, working as Associate Professor, in the Department of Agronomy 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 "Effect of different levels of sulphur and zinc on growth, yield and quality attributes of gobhi sarson (*Brassica napus* L.)"submitted in fulfillment of the requirement for the award of degree of **Doctor of Philosophy (Ph.D.)** in the Department of Agronomy/School of Agriculture, is a research work carried out by Rohit Saral, 12109141, is bonafide record of his/her original work carried out under my supervision and that no part of thesis has been submitted for any other degree, diploma or equivalent course.

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Rohit Saral

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abbreviations/Acronyms

:	Semicolon
%	Percent
Conc.	Concentration
^{0}C	Degree Celsius
Kg/ha	Kilogram per hectare
DAS	Days after sowing
Ag	Agriculture
AAS	Atomic absorption spectrophotometer
C	Carbon
DHA	Dehydrogenase activity
Fig.	Figure
EC	Electrical conductivity
RDF	Recommended Dose of Fertilizer
g	Gram
ha	Hectare
N	Nitrogen
Zn	Zinc
S	Sulphur
K	Potassium

Abstract

A field study was performed at the Agronomy Farm, Lovely Professional University (LPU), Punjab, during the Rabi seasons of 2022-23 and 2023-24. The study aimed to investigate how various levels of sulphur and zinc influence the growth, productivity,and quality attributes of Gobhi Sarson (*Brassica napus L.*).The research setup included four sulphur treatment (S_0: Control, S_1:10 kg/ha, S_2:20 kg/ha, and S_3: 30 kg/ha) combined with four zinc treatment (Z_0 Control, Z_1: Single application, Z_2: Two application, and Z_3: Three application). The factorial randomized block design resulted in 16 distinct treatment combinations, each replicated three times. The study examined seeds, stover, biological yields, along with the harvest index, oil-related parameters of gobhi sarson. Zinc and sulphur application had a substantial effect on all measured yield and quality parameters. The maximum seed yield (2752 kg/ha), stover yield (6841 kg/ha), and total biological yield (9593 kg/ha) were recorded with the Z_3-3 application. The highest oil yield (962.32 kg/ha) and oil content (40.25%) were recorded under the 30 kg sulphur per hectare treatment, compared to S_2 (20 kg: 40.09%, 921.25), S_1 (10 kg: 38.18%, 802.17), and the control (S_0: 36.21%, 689.17). Similar trends in nutrient uptake were found in both stover and seeds. In sulphur levels, maximum values were measured for nutrient uptake, Plant height, fresh and dried weight, and the number of leaves/plant, chlorophyll content, and both primary and secondary leaf counts. Application of sulphur @30kg/ha with three application of zinc (S_3Zn_3) significantly improved the straw, seed and biological yield. The uptake of NPKZNS in both straw as well as seed was significantly higher than in all other treatment.The highest potassium content (0.589% in seeds and 1.633% in stover) and uptake (14.28 kg/ha in seeds and 95.90 kg/ha in stover) were observed under the three zinc application (Zn_3), while the control treatment (Z_0) recorded the lowest values. The study also evaluated the fertility status of the soil and the economic analysis of different treatments, highlighting the cost-effectiveness of S_3Zn_3 due to its superior yields and nutrient uptake.These findings highlight the synergistic outcome of higher zinc and sulphur application on plant development and productivity.

Keywords: Gobhi sarson, Zinc, Sulphur, Growth, Yield, Quality attributes, Soil fertility, Economics

CHAPTER-I

INTRODUCTION

Oilseed crops hold unique significance in the current era of energy crisis, as they play a prominent role in the agricultural industry and export trade of India. The oilseed sector has undergone a dramatic transformation in recent years, wherein oilseeds have become a net foreign exchange earner, leading to the "Yellow Revolution." Edible oils and oil meals have significantly contributed to alleviating malnutrition and meeting the caloric needs of both humans and animals.

In terms of land and productivity, *Brassica napus* (L.), a major rapeseed grain cultivated during the Rabi season. It belongs to family *Brassicacae* and has a chromosome no. of 2n=38. Rapeseed yields edible oil that is widely used for cooking in North India. The seeds and oil are used as condiments in pickles and for adding flavor to curries and vegetables. Additionally, the young leaves are consumed as a vegetable. The oil content in rapeseed seeds ranges from 30 to 48 percent, and the oil is used for cooking and frying. It is also utilized in the production of vegetable ghee, hair oils, medicines, mineral oils for lubrication, and in the manufacture of greases. The residual oil cake is used as cattle feed and manure. This cake contains 25–30 percent crude protein, 5 percent nitrogen, 1.8–2.0 percent phosphorus, and 1.0–1.2 percent potassium.

India ranks third in global rapeseed-mustard production, following China and Canada, and contributes approximately 11 percent of the world's total output. Rapeseed plays a vital role in India's agricultural sector, accounting for nearly one-third of the nation’s edible oil production. With an average yield of 1511 kg/ha, the crop is cultivated on about 66.90 lakh hectares, producing approximately 101.10 lakh tonnes annually (Anonymous, 2022). In Rajasthan, rapeseed and mustard hold significant position among the state's oilseed crops, covering 27.20 lakh hectares. Expanding the area under this crop is not feasible without compromising the cultivation of food grain crops. Thus, the only way to increase the production and its productivity is through new crop production technologies.

Several factors contribute to the low productivity of gobhi sarson in arid region of Punjab are low fertility status and poor physical condition of soil, inadequate and imbalance nutrient availability in soil therefore, emergence of multiple nutrient deficiency. Soil of this region is coarse texture which is poor in organic matter content, low water retention capacity and excessive permeability. The soil's low water retention capacity and the leaching of mobile nutrients contribute to nutrient stress in the root zone. A balanced ratio of various macro and micronutrients is essential for oilseed production. Among these, sulphur plays a crucial and multifaceted role in nourishing oilseed crops, especially those in the cruciferous family. For instance, cereals generally absorb a moderate amount, while oilseeds show a higher demand. This emphasizes that fertilizers lacking sulphur may not support high-yield production effectively. Integrating sulphur-rich fertilizers is, therefore, crucial for achieving sustainable.

Sulphur plays a vital role in several important processes such as protein formation, enzyme activity, and the creation of chlorophyll. These functions contribute to the overall growth and productivity of the plant. Plants take in Sulphur from the soil in the form of sulfate ions and use it to produce proteins and oils, which are crucial for their development and health. Sulphur may be found in agricultural soils in the form of organic materials and liberate slowly through biological decomposition in intensive cropping system, inadequate recycling of crop residues, leaching losses and soil erosion, insufficient application of sulphur containing fertilizer. Soils that are deficient in Sulphur are unable to supply sufficient amounts of this nutrient to meet the crop's needs, leading to Sulphur deficiency in plants and resulting in suboptimal yields (Chattopaddhyay and Ghosh, 2012). Many fertilizers contain significant quantities of sulphur. They can commonly divide into two classes: fertilizers containing Sulphate and fertilizers containing elemental sulphur. Sulphur containing fertilizers (gypsum) immediately provide sulphur to plants in the form of Sulphate but these fertilizers are susceptible to leaching losses. On the other hand, elemental sulphur containing fertilizers needed to convert into Sulphate form before the plants can absorb it and these fertilizers contain very high concentration of sulphur (70-100%). For better assessment of sources which are described as “slow release type” such as elemental sulphur and pyrites, a measurement of residual effect is necessary. They may offer the benefits of continual and slow release of Sulphate during the growth season and thus reduce the leaching losses.

Among secondary and micronutrients, zinc deficiency is increasing and limits optimal production in cereals, pulses, and oilseed crops. The oil seed crops are the most affected as their requirement of sulphur is higher than other crops. Similarly, Zinc hampers the productivity of cereals and oil seed crops (Zizala et al. 2008). Zinc is a crucial micronutrient, essential for crop plants even in minimal quantities. Beyond its fundamental presence, zinc is integral to the biosynthesis of proteins and amino acids, contributing to the formation of key enzymes and metabolic functions that support plant vitality and development. It is a component of important enzymes such as dehydrogenase and proteinases etc. The distribution of zinc found more in roots and it is taken up by plant in Zn^{2+} form, uptake is done by root as well as foliar spray (Pable and Patil, 2011). In order to maximize oil seed production, (Nawaz et al. 2012) investigated the impacts of applying iron and zinc. They found that applying 5 kg/ha of zinc produced the maximum yield response. (Singh 2001) also out that safflower seed production increased synergistically when zinc and sulphur were used together. In a similar vein, (Yadav et al. 2007) showed that the greatest mustard yields, 1536 kg/ha and 1772 kg/ha, represented a 23.89% and 21.84% increase over the control for the 2002–2003 and 2003–2004 seasons, respectively, with 6 kg/ha of zinc was applied.

The current investigation is titled:**“Effect of different levels of sulphur and zinc on growth, yield and quality attributes of gobhi sarson (*Brassica napus* L.)”** was executed during 2022-23 and 2023-24 with the aim of achieving the subsequent objectives:

- ❖ To find out the effect of different levels ofsulphur and zinc on growth and yield of gobhi sarson.
- ❖ To study the effect of different levels of sulphur and zinc on quality of gobhi sarson.
- ❖ To investigate the effect of different levels of sulphur and zinc on fertility status of soil.
- ❖ To evaluate the economics of different treatments

Chapter-II

REVIEW OF LITERATURE

A thorough synopsis that covers the research work carried out on different components of the experiment titled "**Effect of Different Levels of Sulphur and Zinc on Growth, Yield, and Quality Attributes of Gobhi Sarson (*Brassica napus* L.).**" Additionally, findings from other crops have been included where applicable.

2.1 Influence of sulphur on various parameters

2.1.1 Growth

Malhi and Gill (2002) carried out studies evaluate the effectiveness of sulphate fertilization at various growth parameters, yield attributes, seed quality, and sulphur uptake of canola (*Brassica napus* L.).This study showed applied sulphate fertilizer at various growth phases viz. early vegetative, assessed the impact of these fertilization timings on several factors, including seed yield, seed quality (oil content and protein concentration), and the overall sulphur uptake by the plants.

Ahmad et al. (2006) investigated the effect of sulfur (S) application timing on the growth and yield of rapeseed (Brassica rapa L.) under S-deficient conditions. Their study showed that applying 40 kg S ha^{-1} in three split doses across different phenological stages significantly improved biomass accumulation, leaf area index, photosynthetic rate, and seed sulfur content. While sulfur application at planting and during the vegetative stage showed comparable responses, applications during flowering and pod-filling stages did not result in significant yield improvement. The findings suggest that split application of sulfur is more effective than single-dose application for maximizing rapeseed yield.

Makeen et al. (2008) highlighted the significant impact of nutrient management on crop performance. Their findings underscored the importance of optimizing nutrient application for improving yield and quality in various crops.

Yadav and Bohra (2009) conducted a study to assess the impact of different sulphur doses, applied through gypsum and elemental sulphur, on the growth and yield attributes of Indian mustard (cv. Pusa Bold) under varying fertility levels. Their results demonstrated that gypsum application significantly improved growth parameters such as plant height, dry matter accumulation, number of functional leaves, and both primary and secondary branch production, indicating its superiority over elemental sulphur in enhancing vegetative growth.

Kashved et al. (2010) reported that integrated nitrogen management and irrigation significantly enhanced the growth and yield of mustard (Brassica juncea L.). The combined application of 75% recommended nitrogen dose (RDN) through urea and 25% through farmyard manure (FYM) led to significant improvements in plant height, spread, branch number, siliquae count and length, seed weight, and ultimately seed yield. Additionally, applying four irrigations during the rabi season at 100 mm cumulative pan evaporation (CPE) notably improved both growth and yield parameters, highlighting the importance of nutrient integration and timely irrigation for maximizing mustard productivity.

When contrasted with untreated controls, Piri et al. (2011) investigated the combined effects of irrigation frequency and sulphur application on Indian mustard (Brassica juncea) at the Indian Agricultural Research Institute. Their results demonstrated that applying two irrigations—at 45 and 90 days after sowing—markedly enhanced seed yield, dry matter accumulation, and water use efficiency compared to no irrigation. Similarly, increasing sulphur levels up to 45 kg/ha significantly improved crop yield components, harvest index, and soil moisture extraction from deeper layers. The study concluded that optimal irrigation and sulphur supplementation not only boost productivity but also improve economic returns and resource efficiency in mustard cultivation.

Kumar et al. (2011) found that gypsum and pyrite, two different sources of Sulphur, had no effect on the growth properties of Indian mustard. This suggests that the kind of Sulphur given may not have a significant effect on the crop's development.

Rani et al. (2009) demonstrated at the Hayathnagar Research Farm that gypsum application notably improved sunflower growth metrics over elemental sulphur. The study revealed that sulfur deficiency is a major constraint in Alfisols and its supplementation plays a vital role in enhancing oilseed crop productivity and quality. Application of sulfur through both elemental S and gypsum significantly improved seed yield, nutrient uptake, and oil content, with gypsum proving more effective. Furthermore, the oil content showed a strong positive correlation with nitrogen, phosphorus, and sulfur uptake, emphasizing the importance of balanced nutrient management for optimal oilseed production.

Similarly, Kumar et al. (2011) reported from their Allahabad study that gypsum at 45 kg/ha boosted the growth of spring sunflower more effectively than elemental sulphur. Rao et al. (2013) highlighted that sulphur use, regardless of source, significantly enhanced mustard plant growth, with gypsum showing the most considerable plant height, similar to results at doses of (30 or 45) using other forms.

Rakesh and Ganesh (2016) confirmed that 25 kg S/ha as Single Super Phosphate (SSP) improved growth measures in mustard, comparable to 30 kg S/ha of Bentonite-S. Additionally, Kumar et al. (2017) from Bihar noted a significant boost in dry matter production with bentonite sulphur, producing the highest yield at 85.0 g per plant.

Negi et al. (2017) observed significant improvements in growth when different sources of sulphur were applied during their field trials conducted at Pantnagar. The study highlighted the varying effectiveness of these sulphur sources in enhancing plant development.

In a field experiment held out in Navsari, Gujarat, throughout the summer months of 2015–16, Parmar et al. (2018) showed that various sulphur sources considerably improved the germination properties of sesame. The study found that plots treated with ammonium sulphate recorded the highest plant height with results comparable to gypsum application and superior to elemental sulphur.

Kumar et al. (2018) did an experimentat the Agricultural Research Farm, Rajiv Gandhi South Campus, Varanasi. This study revealed that the combined use of sulphur and zinc positively influenced the growth parameters of *Brassica napus*. Among the treatments, the combination with higher levels of sulphur and zinc proved most effective, leading to improvements in plant height, leaf area index, chlorophyll concentration, and the number of branches.

Similarly, Yadav et al. (2019) observed that various sulphur sources notably affected sesame growth attributes. The combination of SSP and gypsum proved to be the most effective for boosting plant.

Singh et al. (2021) did an experiment,applying fertilizer at 100% of the recommended dosage (RDF) supplemented with 40 kg of Sulphur from SSP produced the highest average height of plants and largest amount of stems in mustard.This treatment outperformed lower sulphur levels delivered through bentonite and phosphogypsum.

Additionally, Dubey et al. (2022) conducted research during the Rabi seasons.of 2018-19 and 2019-20 at Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, and Ayodhya. Their findings indicated that, with phosphogypsum yielding the highest values.

Deekshith et al. (2023) experimented with the Shivalik agriculture research and exteNSion centre (SAREC),CSKHPKV, Kangra, Himachal Pradesh. This study shows that treated of gobhi Sarson (*Brassica napus*.)with 100% NPK +Zn@ 25 kg ZNSO4 considerablyimproved height of plant, primary and secondary branches and chlorophyll concentration over other combinations

2.1.2 Impact on yield attributes

Srinivasan and Sankaran (2001) performed an experiment on black gram and reported that gypsum was superior sulphur source which was evident from the yield increase due to gypsum application. Elemental sulphur and pyrite were at par in their effect. Highest benefit cost ratio was also realized from gypsum source.

Duhoon et al. (2005) carried out an investigation in rainfed conditions.at four different locations.to assess the effectiveness of various Sulphur sources. In their experiment, they tested three types of Sulphur sources—elemental Sulphur, gypsum, and single superphosphate—and applied them at three different rates: low, medium, and high. Additionally, they included an untreated control group for comparison. The results revealed that single superphosphate application resulted in significantly higher seed and oil yields in sesame compared to other sources.

In a research the usage of sulphur caused enhanced seedling and the stover outputs. Research further confirmed from Singh et al. (2007), who demonstrated that sulphur addition not only improved seed production but also contributed to enhanced stover outcomes in linseed crops, highlighting the essential role of sulphur in improving crop productivity. Similar trends have been observed across various crops, where sulphur supplementation helps in improving growth parameters, resulting in higher yield potential.

They attributed this improvement to the availability of sulfate (SO_4^{2-}) in gypsum, which is more readily absorbed by plants compared to the sulfide form found in pyrite, which requires oxidation before being utilized by crops.

Sharma and Arora (2008) conducted a two-year study under rainfed conditions and found that the optimal dose for mustard crops was 25 kg/ha of sulphur, particularly from ground gypsum, which enhanced crop growth. Yadav and Bohra (2009) found that increasing fertility of the recommended doseled to a significant improvement in yield attributes.

Deshmukh et al. (2010) in Jabalpur, Madhya Pradesh, concluded that sulphur application from different sources like single superphosphate, and gypsum significantly enhanced sesame seed yield. When compared to other resources, mineral sulphur was the most successful in increasing both seedling and stover productivity.

Pati et al. (2011) examined the effects of phosphogypsum and magnesium sulphate at varying levels on sesame yield and sulphur uptake in West Bengal. Their results indicated that magnesium sulphate at 60 kg/ha led to the highest grain yield, followed by phosphogypsum at the same rate. The highest stover yield was observed with magnesium sulphate at 90 kg/ha.

Chattopadhyay and Ghosh (2012) reviewed several sulphur sources, including single superphosphate, phosphogypsum, pyrites, and elemental sulphur, and found that all had significant impacts. When compared to alternative sources of Sulphur, ammonium sulphate produced noticeably better production of seeds and straw in mustard plants, according to research by Kumar and Trivedi (2012). The best results were obtained using ammonium sulphate.

Rao et al. (2013) examined that S usage notably affects the yield-related parameters and the overall yield of groundnut compared to the untreated control, specifically, along with significant increases.

Guptaet et al. (2014) did an experimentat SKUAST-Jammu and observed that incorporating sulphur and zinc along with NPK and vermicompost in a maize-gobhi sarson cropping sequence enhanced the yield of gobhi sarson related to the control and other treatment combinations

Rakesh and Ganesh (2016) implemented a field test in which the use of a single superphosphate was found to significantly improve seed quality and yield attributes in mustard and stover outcomes. Comparable improvements were observed with Bentonite-S applied at 30 kg S/ha, indicating that both treatments enhanced mustard yields similarly.

The effects of sulphur treatment on sunflower development and yield were examined by Ravikumar et al. (2016). According to their research, development, harvest characteristics, and nutrient absorption were all positively impacted elemental sulphur in conjunction with the recommended fertilizer dosage (RDF). The control treatment, on the other hand, produced the worst outcomes since no sulphur was added.

Kumar et al. (2017) conducted a study in Bihar where they found that Sulphur source and dosage significantly influenced the yield of mustard. Bentonite Sulphur applied at 60 kg ha-1 outperformed other Sulphur sources in promoting higher seed yield and stover production.

In contrast to gypsum and pyrite sources, Bentonite sulphur applied produced the maximum mustard yield, especially in terms of seed yield and stover output, according to further study conducted by Kumar et al. (2018) at Bihar Agricultural College. Elements sulphur sprayed produced the longest siliquae and the largest stover output in mustard, according to a different research by Kumar et al. (2018a) in Varanasi.

Parmar et al. (2018) conducted research demonstrated that the application of various Sulphur types improved sesame yield, with ammonium sulfate proving to be more effective than elemental sulphur. Their results indicating that bentonite Sulphur had a significant positive impact on yield and economic returns in mustard cultivation.

When sulphur was sprayed using a mix of SSP and gypsum, as opposed to alternative sulphur sources, Yadav et al. (2021) in Bikaner saw notable increases in both the seed and stalk productivity of sesame.

Dwivedi et al. (2021) conducted a study in Azamgarh and found that the application of gypsum as a Sulphur source led to significant increases in mustard yield, siliquae length, and both the seed and stalk productivity

According to Singh et al. (2021), mustard produced the greatest quantity of siliquae and siliquae length when 100% of the prescribed fertilizer dosages were applied in addition to 40 kg of sulphur from SSP.

Dubey et al. (2022) at Kumarganj, Ayodhya found that phosphogypsum as a Sulphur source led to significantly better yield attributes and seed quality in mustard compared to other sources, including elemental Sulphur, although it was comparable to single superphosphate.

In a research study at Banaras Hindu University, Sukirtee et al. (2022) found that raising the amounts of sulphur and nitrogen respectively, greatly increased stover and seed productivity, with large increases in siliquae number and seed weight.

2.1.3 Impact and Quality, Nutrient content, and Uptake

Singh & Singh (2007) executed a field study at Bichpuri, Agra, the impact of different Sulphur sources and application rates on the productivity and nutrient uptake of linseed was evaluated.

Kumar and Kumar (2008) considered the outcome of varying levels of N and S on growth factors of mustard. The findings indicated that the onset of 50% flowering and 50% pod formation occurred significantly earlier in plots treated with nitrogen as compared to no fertilizer application.

Similarly, Pati et al. (2011) investigated the sulphur uptake in sesame (cv. Rama) at Sriniketan, West Bengal, using various Sulphur sources like phosphogypsum and magnesium sulfate, applied to red and lateritic soils. Magnesium sulfate was found to be the most effective source for increasing total Sulphur uptake at all levels, followed by phosphogypsum. All Sulphur treatments resulted in a significant rise in available Sulphur in the soil compared to the control.

Ammonium sulphate (39.2%) created the maximum quantity of oil in the seeds of mustard, which was suggestivelygreater compared to other sources. The other sources in decreasing order of effectiveness were gypsum (38.5%), single super phosphate (SSP) and pyrite.

Rai et al. (2014) looked at how mustard crops were affected by varying Sulphur levels and found a significant improvement in nutrient uptake, yield, and nutrient content when sulphur was applied at various levels. Outperforming other treatments, gypsum sprayed was the most favorable Sulphur source in increasing productivity as well as nutrient absorption.

Saini et al. (2015) executed a field study in Sardar Krushinagar where they sprayed gypsum as a sulphur source resulted in the highest nutrient content (N, P, S, Zn) in sesame seeds and stalks, as well as the greatest uptake of these nutrients, compared to other sulphur sources.

Rakesh and Ganesh (2016) reported that sulphur application significantly improved growth, yield, and oil content of mustard, with 25 kg S ha^{-1} through SSP showing maximum yield and quality. However, the highest sulphur uptake was observed at 30 kg S ha^{-1} applied as bentonite-S. They concluded that bentonite-S enhanced sulphur absorption, while SSP was more effective in improving yield up to an optimal level. Agronomic use efficiency declined with higher sulphur doses, emphasizing the need for balanced application.

At the Agriculture College, Nagpur research farm, Adkine et al. (2017) found that applying 54 kg S per ha through gypsum produced the greatest oil (40.65%) and protein (19.93%) contents in mustard seeds.

Kumar et al. (2017) executed a field experiment outperforming other types of sulphur treatments previously used. This result suggests that bentonite Sulphur is particularly effective in enhancing the oil quality of mustard, making it a superior option for improving seed oil content.

Negi et al. (2017) studied the consequences of Sulphur sources in Pantnagar and discovered that using gypsum and Zypmite increased the quantity of Sulphur and nitrogen in both stovers in the soil.

Kumar et al. (2018) conducted a study at Bihar Agricultural College, Sabour, Bhagalpur, and reported that mustard exhibited the highest sulphur content and uptake at all growth stages when Bentonite sulphur was applied, demonstrating significant advantages over gypsum and pyrite.

Parmar et al. (2018) studied sesame cultivation at Navsari, Gujarat, during the Rabi season and found that the highest protein and oil yields were obtained. This treatment was found to be as effective as gypsum.

Sahoo et al. (2018) found that applying S to mustard, whether via SSP, gypsum, or elemental sulphur, greatly enhanced the plant's absorption of sulphur. The increase in sulphur uptake ranged from 65% to 107% higher than the control, depending on the source.

To assess the impact of varying Sulphur levels on mustard growth, yield, and nutrient absorption, Yadav et al. (2019) undertook a field experiment in Varanasi. They discovered that gypsum application resulted in the highest concentrations.of NPK and S in both seeds and stalks, along with superior nutrient uptake.

Singh et al. (2021) performed a study in Faizabad, Uttar Pradesh, during the Rabi season and found that the treatment was more effective than lower sulphur levels applied through sources like Bentonite or phosphogypsum.

Tiwari et al. (2021) indicated that Bentonite sulphur, applied at the appropriate rate, resulted in the highest uptake by the plants, outperforming the control treatment and contributing to better growth and productivity.

Stepaniuk and Głowacka (2021) concluded that fertilized with different sulphur doses 40 and 60 kg applied in different method of application sowing, foliar application and soil application sowing + foliar application in oilseed rape (*Brassica napus* L. *var. napus*) significantly enhanced seed yield and straw yield.

2.1.4 Impact on soil fertility

Akbari et al. (1999) observed that post-harvest application of these nutrients can improve soil fertility by replenishing it and ensuring that essential elements are present at higher concentrations, which benefits the growth and productivity of future crops. Notably, the addition of gypsum atimproved the soil's manganese condition and increased iron availability.

Kaya et al. (2009) explored the effects of elemental Sulphur and Sulphur-containing waste materials on soil properties and nutrient dynamics. Their study showed that Sulphur application led to a decrease in soil pH, while simultaneously increasing nutrient concentrations in both plant tissues and the residual nutrients available in the soil.

In an experiment conducted by Yadav and Chhipa(2007), gypsum applied at 50% of the recommended dose (GR). The combined application of both gypsum and pyrite at 50% GR.

Tripathi et al. (2010) carried out a study at Pant Nagar and experimental that the combined application of the recommended NPK dose (120 kg N, 17.6 kg P, 16.7 kg K ha^{-1}) fertilizers along with seed treatment using Azotobacter, resulted in higher dry matter accumulation in mustard compared to the control.

Makoi and Verplancke (2010) found that using gypsum as a soil amendment significantly enhanced several soil properties. These improvements included a reduction in exchangeable sodium levels and an increase in the soil's available water capacity. This suggests that gypsum can effectively improve soil structure and water retention, which can lead to better soil health and plant growth conditions. Although gypsum application led to a gradual decrease in hydraulic conductivity (Ks), this effect was not fully reversed, potentially due to soil compaction caused by heavy rainfall or the equilibrium between ions in the soil material.

Singh and Singh (2014) investigated the impact of gypsum amendments on micronutrient levels and chemical properties of soil. Their findings showed that gypsum application effectively improved soil chemical properties, including reducing both electrical conductivity (EC) and soil pH, which enhanced the availability of essential micronutrients. However, there were no significant changes levels in the soil following the application of various Sulphur sources.

Abhiram et al. (2016) evaluated the effects of different Sulphur sources (elemental Sulphur, ammonium sulfate, and gypsum) and application rates (10, 20, and 30 kg ha-1) on soil properties and the availability of major and secondary nutrients under maize cultivation. Their findings indicated no significant differences in soil pH and electrical conductivity between the treatments, suggesting minimal impact on these soil properties.

In a study conducted by Kumar et al. (2017) in Bihar, it was observed that the highest levels of available Sulphur in the soil after mustard harvest were obtained with bentonite sulphur, highlighting effectiveness of this Sulphur source in maintaining soil Sulphur levels.

Singh et al. (2017) conducted an experiment in Meerut with green gram and found that increasing Sulphur levels led to a decrease in soil pH. Gypsum was particularly effective in lowering the soil pH compared to elemental Sulphur. However, the usage of different sulphur sources had no discernible effect on the nitrogen levelsin the soil after crop harvest. Despite this, the study noted a greater build-up of these nutrients in the soil when gypsum was used as the Sulphur source.

Rashmi et al. (2018) emphasized that gypsum serves as a cost-effective and readily available source of sulfur, effectively addressing sulfur deficiency while also enhancing the physico-chemical properties of the soil. As a moderately soluble source of both calcium and Sulphur, gypsum enhances overall plant growth and improves soil structure. Additionally, it plays a role in reducing soil erosion and nutrient losses, particularly phosphorus, in surface water runoff.

In order to assess the impact of three distinct Sulphur sources—phosphogypsum, bentonite, and a control—on mustard yield and economic performance, Kumar et al. conducted an experiment in Bihar in 2019. The findings further demonstrated the effectiveness of bentonite as a Sulphur source for mustard cultivation by showing that it produced the maximum accessible Sulphur content in the soil following mustard harvest when paired with the approved dosage of NPK.

2.1.5 Effect on economics

Kumar et al. (2017) conducted a field experiment during the winter season of 2015–16 at IFTM University, Moradabad (U.P.), to assess the impact of NPK, sulphur, and FYM on mustard (*Brassica juncea* L.) performance. The results indicated that the combined application of 75% recommended NPK with 40 kg S ha^{-1} and 10 MT FYM ha^{-1} significantly improved growth parameters, yield attributes, and quality. This treatment recorded the highest plant height (174.63 cm), number of branches per plant (24.47), siliquae per plant (381.40), 1000-seed weight (5.52 g), seed yield (1541.5 kg ha^{-1}), and stover yield (5161.0 kg ha^{-1}), along with superior oil and protein contents. Furthermore, it achieved the highest net return (Rs. 33,119.4) and a favorable B:C ratio (1.04), underscoring the effectiveness of integrated nutrient management in mustard cultivation.

The experimental results by Kumar et al. (2018) showed that elemental sulphur application for mustard, demonstrating its superior economic potential

Parmar (2018) executed a study in Navsari, Gujarat, to assess how various Sulphur sources affected the production of sesame. Their findings demonstrated that ammonium sulfate was the most economically feasible Sulphur source for enhancing sesame yields in the area.

In 2019, Kumar highlighted the study in Bihar to assess the effects of various Sulphur sources, including phosphogypsum, bentonite, and a control, on mustard yield and economic performance.

2.2 Impact of zinc

2.2.1 Growth parameters

Ismail and Azooz (2005) observed that as the application of zinc increased, the zinc concentration was found to be higher in the roots than in the shoots. Additionally, membrane permeability also showed an increase with the application of higher zinc doses, such as 0, 2.5, 5.0, 7.5, and 10 mg kg^{-1} of soil.

Jat et al. (2012) during the 2001–2003 periods, both seed and stover yields were enhanced as zinc levels increased. The biological yield showed significant improvement at a zinc application rate of 5.0 kg/ha, but no further increase in yield was observed with higher zinc doses beyond this rate.

Shehu (2014) exceuted a field experiment at the Food and Agricultural Organization's Tree Crop Programme Teaching and Research Farm at Adamawa State University, Mubi, to assess the effects of (Mn) and (Zn) on the shoot content, uptake. The treatments included various combinations of NPK and different levels of Mn and Zn, such as NPK + 0.5 kg Mn/ha, NPK + 0.5 kg Zn/ha, and other combinations with higher doses of both micronutrients. The results indicated that stem height, branch number, and leaf count were not significantly affected by the application of Mn and Zn.

Sahito et al. (2014) evaluated the effect of varying zinc levels (0, 2, 4, 6, 8, and 10 kg Zn ha^{-1}) on two mustard varieties, Early Mustard and S-9, under field conditions in Sindh. The study revealed that increasing zinc levels significantly enhanced growth parameters, seed yield, and oil content. The highest zinc dose (10 kg ha^{-1}) resulted in the tallest plants (216 cm), highest number of pods per plant (574.50), seed yield (2037.20 kg ha^{-1}), and oil content (36.80%). Among varieties, S-9 outperformed Early Mustard in all measured traits, producing superior growth, seed yield (1960.30 kg ha^{-1}), and oil percentage (36.80%). Based on the findings, zinc application at 8 kg ha^{-1} and the cultivation of variety S-9 were recommended for enhanced productivity and profitability in mustard cultivation.

Sirothia and Chaturvedi (2016) found that the combination of 60 kg phosphorus and 10 kg zinc in the form of EDTA significantly improved growth, grain yield, and stover yield in mustard.

Mohato et al. (2022) reported that highest enhanced in height of plant, leaf area index, crop growth rate along with dry matter accumulation while use the nano iron sulphide along with 100% recommended dose of fertilizer in gobhi sarson (*brassica napus*).

2.2.2 Impact on yield attributes

Singh and Singh (2005) explored how nitrogen (N), sulphur (S), and zinc (Zn) application impact Indian mustard growth.

Patil et al. (2006) explored the combined study of (B) and (Zn) using borax and zinc sulfate ($ZNSO_4$) at Dharwad, during the 2000 ***kharif*** season. Zinc sulfate was applied at sowing, while borax was used at 2 kg/ha and included a foliar spray of borax (0.1%) and $ZNSO_4$ (0.1%). Results exposed a significant increase in seed count, yield, and related growth parameters.

Yadav et al. (2007)explored the impact of Zn and S on Indian mustard grown on medium-fertility soil. The highest growth and productivity, achieving grain yields of 1536 kg/ha and 1772 kg/ha in consecutive years, representing a 23.89% and 21.84% increase over control plots.

Tripathi et al. (2011) discovered that adding farmyard Azotobacter to the recommended fertilizer regimen led to significant increases in nutrient concentrations.Within the plants.

Jat et al. (2012) reported that stover yields saw marked improvement at this level, though further increases in zinc application did not show significant additional benefits in biological yield.

Guptaet al. (2014) did a field study at SKUAST-Jammu and examined that integrating sulphur along with zinc application with NPK fertilizers and vermicompost in a maize-gobhi sarson cropping sequence led to superior results. This treatment combination resulted in enhanced protein content, oil yield in gobhi sarson.

Kumar et al. (2018) carried out a research trial at the Agricultural Research Farm, Rajiv Gandhi South Campus, and Varanasi. Their findings highlighted the significant role of S and Zn application in improving the growth, yield attributes, and overall productivity of Brassica napus. The optimal combination, identified as 40 kg S ha^{-1} along with 10 kg Zn ha^{-1}, exhibited the most favorable outcomes for enhancing growth and yield performance in the crop.

Waraich et al. (2022) investigate the significantly impact of foliar application sulphur on canola (*Brassica napus* L.) growth attributes, yield parameters, and physiological traits under heat stress conditions.This study found that sulphur-treated plants show improved physiological attributes, such as increased chlorophyll content, increased photosynthetic rate, and better antioxidant defence mechanisms.

2.2.3 Quality parameters

The study by Tripathi et al. (2011) concluded that that the nutrient concentrations of (NPKSZnB) in both seed and stover yields were highest when full RDF was applied. Furthermore, the study showed that soil fertility levels were enhanced progressively with the addition of organic and micronutrient supplements, demonstrating that each addition contributed to better nutrient enrichment and plant health.

Singh and Singh (2005) studied the effects of nutrient application on Indian mustard, specifically focusing on certain key nutrients. They found that applying Sulphur led to significant improvements in seed yield and oil content compared to untreated plants, while applying zinc also boosted these parameters, though to a lesser extent. Additionally, using a combination of nitrogen, Sulphur, and zinc notably increased the protein content in the seeds. This shows that balanced nutrient management can enhance both the yield quality and nutritional value of mustard.

Deo and Khandelwal (2009) conducted a field study during the 2001–02 and 2002–03 Rabi seasoNS to examine the effects of nutrient application on mustard grown in loamy sand soil that had been treated with gypsum and irrigated with water containing high levels of sodium carbonate. They applied different levels of phosphorus and zinc to see how these nutrients impacted crop growth and yield. The goal was to understand how these nutrients could help improve mustard performance under challenging soil and water conditions, enhancing the overall productivity and sustainability of the crop.

A field experiment conducted by Sushma et al. (2024)demonstrated that the integrated application of 75% of the recommended dose of fertilizers (RDF), supplemented with 22.5 kg sulphur, 3.7 kg zinc, 2.5 tons per hectare of farmyard manure (FYM), and two foliar sprays of nano urea—administered at 30-35 days after sowing (DAS) and during the pre-flowering stage—resulted in marked improvements in growth and yield parameters of yellow mustard (Brassica rapa var. yellow sarson). Key growth attributes such as height of plant (141.03 cm) as well as dry weight accumulation (37.76 g/plant) were significantly enhanced. Yield components, including the number of siliqua/plant (142), siliqua length (6.67 cm), and test weight (3.43 g), were also substantially improved. This treatment produced a seed yield of 1.49 tons per hectare and a stover yield of 3.54 tons per hectare, outperforming the control treatment by a wide margin. The findings underline the effectiveness of combining balanced fertilization, micronutrient supplementation, and nano urea application in boosting mustard productivity.

2.2.4 Effect on soil fertility

Akbari et al. (1999) found that higher doses of S, Fe, Mn, and copper significantly increased their levels in the soil after the wheat harvest. They also observed that applying gypsum at 4 tons per hectare improved the availability of iron and raised the manganese levels.

Kaya et al. (2009) reported that usage of elemental Sulphur and S-containing waste resulted in a decrease of soil pH, but general increase in nutrient concentrations.for both plants and increase in residual available nutrient concentration in the experimental soils.

Kumar et al. (2019) were carried out an experimental study at Bihar to evaluate the influence of sulphur (*i.e*., Phosphogypsum, Bentonite and Control) on bentonite as sulphur source with recommended dose of NPK had recorded the highest amount of available sulphur.

2.2.5 Effect on economics

Kaur et al. (2017) executed a field study to evaluate how the application of a standard fertilizer dose, either with or without the addition of Zn and B. The study aimed to understand the impact of these additional nutrients on the performance of the mustard plants when combined with the recommended fertilizer. The results showed that supplementing RDF with zinc and boron significantly improved the yield attributes compared to using RDF alone. Although the yield was similarly enhanced with both higher and moderate levels of zinc, the application of RDF with a moderate level.

2.3 Interactive impacts of Sulphur and Zinc Levels

Numerous studies have demonstrated that the combined application of Sulphur (S) and zinc (Zn) enhances mustard productivity, growth, and yield. According to Jat et al. (2008), combining Sulphur (S), zinc sulfate ($ZNSO_4$), and iron sulfate ($FeSO_4$) in optimal amounts led to significant improvements in important factors related to crop yield, such as test weight (the weight of seeds), seed production, and the amount of stover (the non-edible parts of the plant like stems and leaves). Similarly, Baudh et al. (2012) observed that increasing the levels of Sulphur and zinc resulted in better crop yields, indicating that higher amounts of these nutrients positively impacted the overall production of the crop and reproductive performance, including higher numbers of capsules and greater seed output, with the most effective results seen at enhanced levels of both nutrients.

The research highlighted the significant positive effects of applying sulphur in combination with zinc on mustard yield. Specifically, the addition of zinc up to 5 kg per hectare, along with sulphur levels as high as 40 kg per hectare, led to notable improvements in key growth traits. Additionally, further studies indicated that a specific combination resulted in the highest economic return from mustard cultivation, showing that the right balance of these nutrients not only boosted yield but also increased profitability.

Similarly, Mishra et al. (2016) identified the most effective treatment for maximum seed yield combined with recommended doses of NPK under rainfed conditions.

Singh and Pandey (2017) observed significant improvements in mustard yield with further increases in yield. Experiments by Sipal et al. (2016) supported these findings, noting that the highest growth and yield parameters in mustard were achieved. These results are further corroborated by Kumar et al. (2018), who demonstrated the impact on rapeseed growth, highlighting the significant influence of these nutrients on yield attributes and yield.

Verma et al. (2018) also investigated the morphophytological respoNSes of crops to varying doses of zinc and sulphur, concluding that their interaction significantly influenced all plant parameters, with the highest growth recorded.

Deekshith et al. (2023) experimented with the Shivalik agriculture research and exteNSion centre (SAREC), CSKHPKV, Kangra, Himachal Pradesh. This study shows that treated of gobhi Sarson (*Brassica napus*.) with 100% NPK +Zn@ 25 kg ZNSO4 considerably increased primary branches per plant, secondary branches/plant and chlorophyll content over other combinations

Reddy et al. (2024)shown a research trial at the research farm of LPU, Punjab and stated that application of 75%RDF +1% Urea + 0.5% FeSO4 + 0.5% ZNSO4 significantly improved plant height, dry weight, fresh weight, primary branches, secondary branches of gobhi sarson as compare to rest combination of treatments.

CHAPTER-III

MATERIALS AND METHODS

To examine the **"Effect of different levels of sulphur and zinc on growth, yield and quality attributes of gobhi sarson (*Brassica napus* L.)"** a field experiment was conducted during the rabi seasons of 2022–23 and 2023–24 at the Agricultural Research Farm, Lovely Professional University, Punjab. The field experiment was conducted on gobhi sarson (*Brassica napus* L., var. GSC-7) using a Factorial Randomized Block Design (FRBD) comprising 16 treatment combinations with three replications, totaling 48 plots. The treatments included four levels of sulphur (S_0, S_1, S_2, S_3) and four levels of zinc (Z_0, Z_1, Z_2, Z_3), applied at various growth stages

3.1 Description of Geographical Location of Research Site

During *rabi* season (2022-23 and 2023-24, the Lovely Professional University in Punjab was the site of the experiment. The farm is situated at average height of 245 m above (sea level), at 31°22' North latitude and 75°23' East longitude. The soil in the area can be classified as either sandy loam or alluvial plain. Major crops cultivated in this region include rice, wheat, maize, groundnuts and barley. The region experiences distinct weather patterns with warm and dry summers, wet and humid monsoons, and cold and windy winters.

3.2 Climate and weather conditions

The test area experiences a subtropical climate characterized by high night time temperatures and prolonged hot winds during the summer. May, June, and July are the hottest months, with temperatures reaching up to 45 ℃. Typically, the last week of July marks the beginning of a temperature decline, indicating the approach of winter in October. December and January are the coldest months, with chilly mornings often reaching winter-like conditions. Rainfall in winter is sporadic and uneven. The region receives an annual average of 703 mm of precipitation, with the majority occurring in July, August, and September. About 70% of the annual rainfall occurs throughout the southwest monsoon period, from July to September.

3.3 Meteorological data of crop season

The results of agricultural cultivation are significantly influenced by weather and climate, so prevailing conditions during the crop's growing season must be carefully considered. These conditions impact all related agricultural activities. Therefore, an assessment of climate data collected during the crop's growth period is essential. In this context, the data from the analysis of climate parameters are summarized in Table 3.1 It is important to note that the crop was planted during the *rabi* season of 2022-23 and 2023-24.

Table 3.1 Standard meteorological monthly mean data from November-April (2022-23 and 2023-24)

SMW	Period	Temperature (°C)				Relative humidity (%)				Total rainfall (mm)		Rainy days*		Wind speed km h^{-1})		Evaporation (mm day^{-1})	
		Maximum		Minimum		Maximum		Minimum									
		Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
44	29 Oct.- 04 Nov.	31.5	33.5	16.1	13.9	62	56	28	17	0.0	0.0	0	0	3.4	2.7	3.3	5.3
45	5-11 Nov.	32.1	33.5	16.5	13.3	65	65	30	30	0.0	0.0	0	0	3.5	2.2	3.8	4.1
46	12-18 Nov.	29.7	32.0	17.5	14.8	90	59	40	24	17.0	0.0	1	0	2.9	3.8	2.7	4.1
47	19-25 Nov.	27.2	31.0	11.9	13.2	79	76	27	28	0.0	0.0	0	0	3.4	2.6	2.1	4.0
48	26 Nov.-2 Dec.	26.6	27.2	8.8	11.8	66	68	16	30	0.0	0.0	0	0	2.4	2.4	2.1	2.3
49	3-9 Dec.	23.9	28.8	7.6	11.1	68	78	24	32	0.0	0.0	0	0	3.5	2.6	2.0	3.0
50	10-16 Dec.	24.2	24.9	6.1	5.7	65	62	22	21	0.0	0.0	0	0	3.3	2.8	2.0	2.7
51	17-23 Dec.	25.4	23.6	6.1	5.1	74	72	27	27	0.0	0.0	0	0	3.2	3.9	2.4	2.0
52	24-31 Dec.	20.8	21.1	4.3	3.1	94	78	42	30	3.0	0.0	1	0	4.1	3.3	2.1	2.0
1	1-7 Jan	22.7	15.5	9.2	2.0	85	99	42	56	1.0	0.0	0	0	4.1	4.6	1.9	0.9
2	8-14 Jan	15.4	19.8	3.6	2.9	97	73	62	36	0.0	0.0	0	0	4.7	3.5	1.1	1.0
3	15-21 Jan	22.0	22.5	4.9	4.8	94	58	30	14	0.0	0.0	0	0	3.9	5.0	1.3	1.7
4	22-28 Jan	25.6	23.6	11.4	5.6	77	71	24	19	0.0	0.0	0	0	2.7	4.9	2.7	2.0
5	29 Jan-4 Feb	26.7	24.1	12.2	7.4	68	80	18	22	0.0	0.0	0	0	5.8	4.0	3.7	2.1
6	5 -11 Feb	26.9	27.5	12.3	10.1	53	75	12	20	0.0	0.0	0	0	6.8	7.1	3.8	5.0
7	12-18 Feb	24.2	23.8	9.4	10.7	64	83	17	41	0.0	7.8	0	1	5.1	4.8	5.7	4.7
8	19-25 Feb	27.9	24.2	13.2	9.7	63	85	22	38	0.5	0.8	0	0	4.9	5.2	5.1	4.1
9	26 Feb- 4 March	33.7	23.4	19.2	10.5	56	92	19	42	0.0	3.6	0	1	6.4	7.1	6.1	3.7
10	5-11 March	30.6	27.5	16.6	11.3	64	76	21	24	0.0	0.0	0	0	5.8	5.8	4.1	5.3
11	12-18 March	36.6	35.4	20.9	16.0	50	53	12	11	0.0	0.0	0	0	6.5	5.5	6.7	6.6
12	19-25 March	39.8	35.3	23.1	17.9	35	43	09	10	0.0	0.0	0	0	7.3	6.8	8.8	7.4
13	26 March- 1 April	39.6	37.3	23.4	19.1	32	50	10	13	0.0	0.0	0	0	6.5	5.8	8.7	10.1

Y_1 = 2022-23; Y_2 = 2023-24;

Data collected from Agromet Observatory, School of Agriculture, LPU, Phagwara, Punjab SMW = Standard Meteorological Weeks

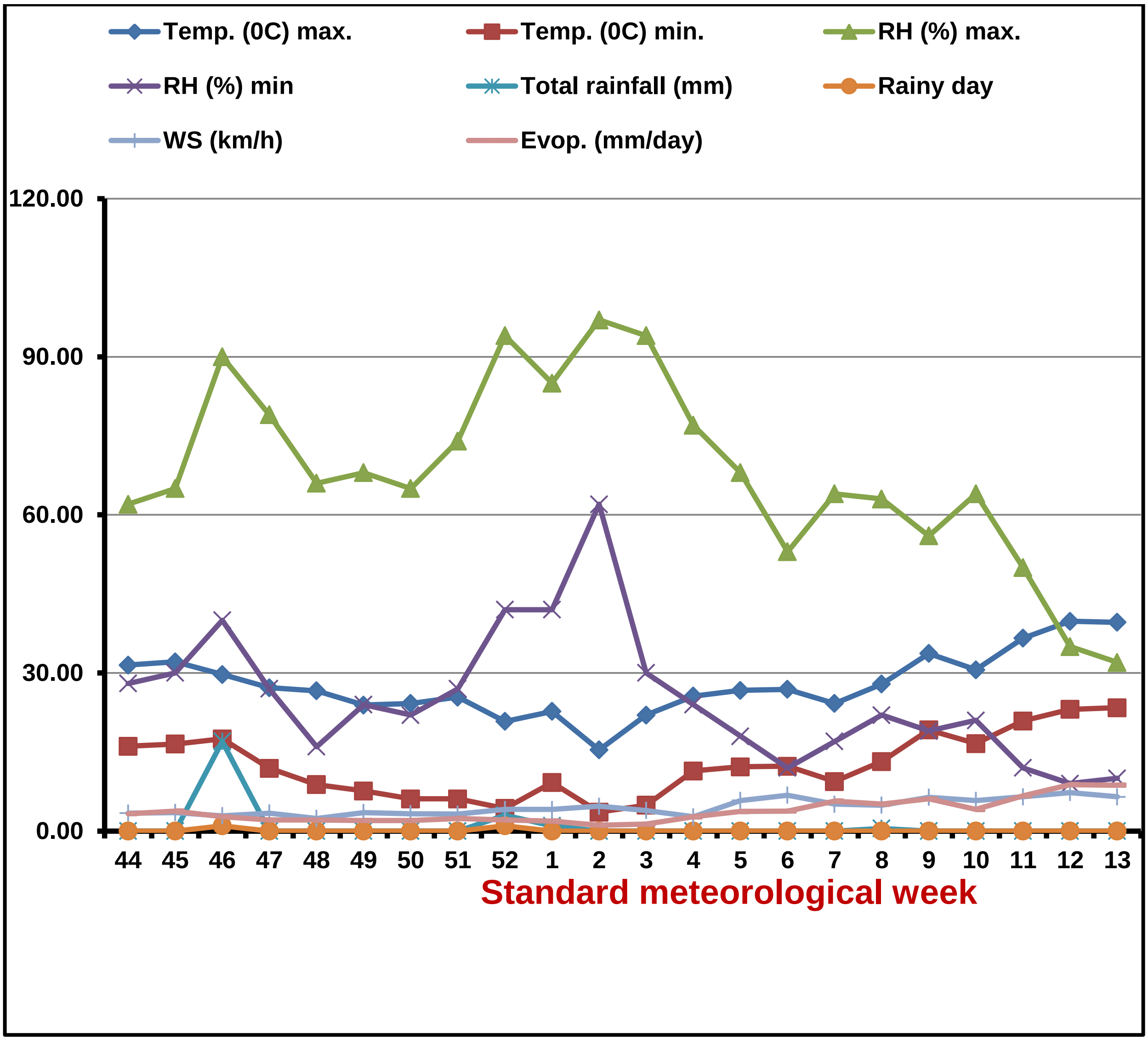


Figure 3.1 (a): Mean weekly meteorological data recorded during *rabi* season (2022-23)

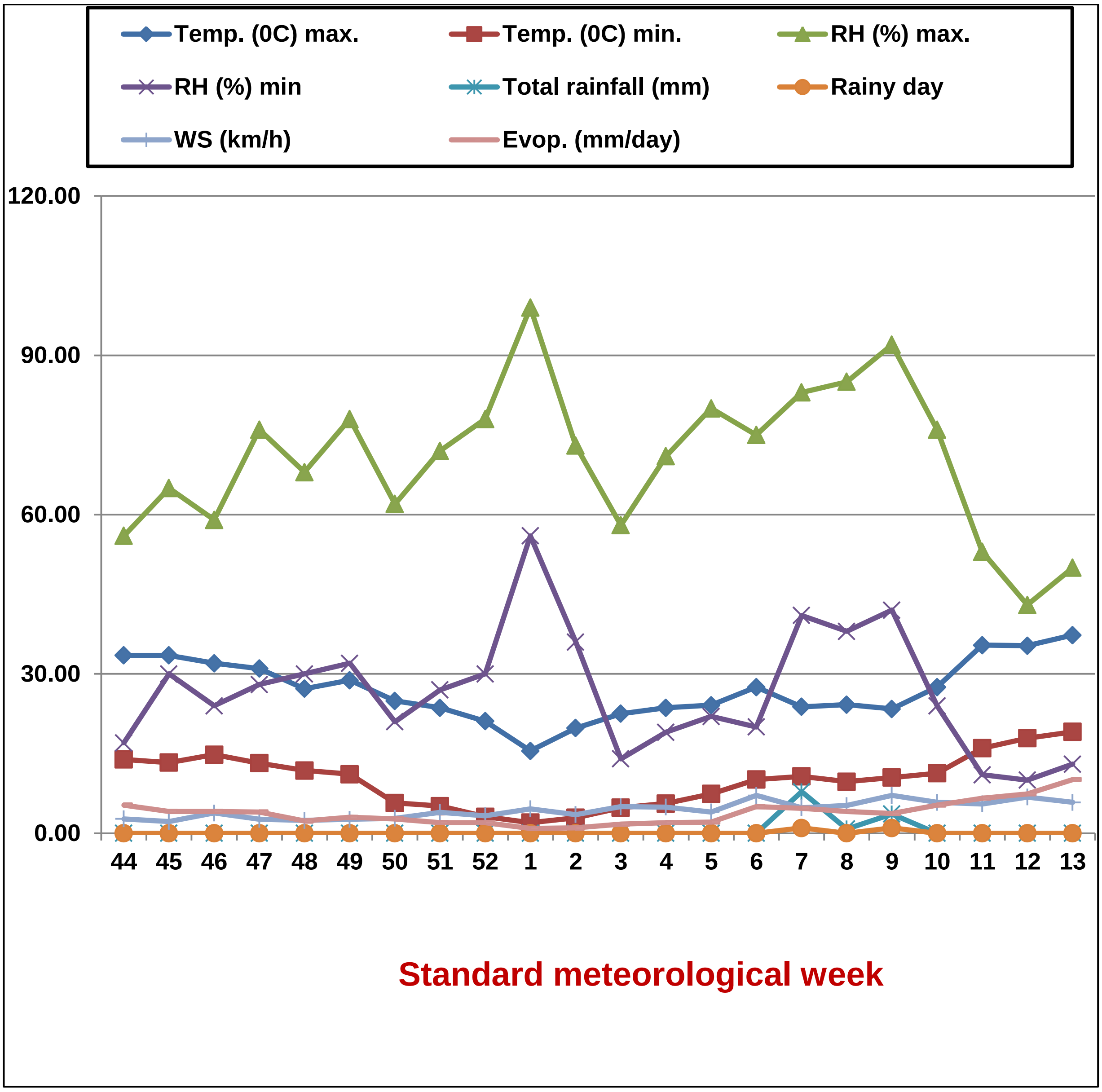


Figure 3.1(b): Mean weekly meteorological data recorded during *rabi* season (2023-24)

3.4 Analysis of Soil from the Experimental Field

To assess the soil's mechanical, physical, and chemical attributes, samples were taken from the top layer of each experimental replication, which measured 0-30 cm. These samples were combined, air-dried, and sifted to create a composite sample. Subsequently, this composite sample underwent examination to determine its mechanical, physical, and chemical properties. Table 3.2 presented below provides the findings obtained from these samples along with the analysis methods employed.

3.4.1: Properties of soil

Soil properties were examined using various standard procedures, including measuring soil pH, electrical conductivity (EC), and macronutrient content.

- **Soil pH:** This was determined using a calibrated (pH meter). Soil samples were collected from various field depths and stored in polythene bags to prevent contamination. Approximately 12.5 g of soil was weighed and transferred into a 150 ml beaker. Distilled water (50 ml) was added, and the suspension was stirred for 30 minutes to create a uniform mixture. Before measurement, the pH meter was calibrated using standard buffer solutions. The electrode of the pH meter was immersed in the soil-water mixture, and the pH value was recorded.
- **Soil Electrical Conductivity (EC):**The EC was measured using an EC meter. For this, 10 g of air-dried soil was weighed and transferred into a bottle. A volume of 50 ml of distilled water was added, and the solution was agitated on a mechanical shaker for one hour to ensure the dissolution of soluble salts. Prior to sample measurement, the EC meter was standardized using a 0.01 M KCl solution. The EC readings were then obtained by immersing the electrode into the soil extract.
- **Nitrogen Content**: The N content in soil and plant samples was determined through a three-part process: digestion, distillation, and titration.
- **Digestion:** one gram of soil was carefully weighed and transferred into a digestion tube. Subsequently, 10 millilitres of concentrated sulphuric acid were added, followed by the inclusion of 5 grams of a catalyst mixture to facilitate the reaction. The digestion process began at a controlled temperature of 100°C and was gradually increased to 360°C to ensure thorough breakdown of the organic matter. The progress of digestion was monitored visually, with the solution first transitioning to a

light green hue before ultimately becoming completely colourless, signalling the completion of the process.

- **Distillation:** Once the digestion process was complete and the sample was allowed to cool, the digested material was prepared for distillation. During this step, a hose was submerged into a solution containing 20 millilitres of 4% boric acid. To initiate the distillation, 40 millilitres of sodium hydroxide (NaOH) were added to the distillation unit. As the mixture was heated, ammonia gas was released and subsequently captured in the boric acid solution. This caused a noticeable color change in the solution, shifting from pinkish to green. To ensure the accuracy of the procedure, a blank sample was processed alongside the experimental samples for quality control.
  - ❖ Titration: The final step involved titration with 0.02 N sulphuric acid, noting the volume used when the colour changed from greenish to pink.
- **Available Phosphorus:** The Olsen method was employed to estimate the available phosphorus in the soil. A 1 g soil sample was placed into a 150 ml conical flask along with a small amount of activated charcoal to assist with clarification. Sodium bicarbonate ($NaHCO_3$, 0.5 N) solution was added, and the mixture was shaken for half hour to ensure thorough extraction. The resulting suspension was filtered. From the filtrate, 5 ml was transferred into a 25 ml for further analysis. A blank solution was prepared under the same conditions for comparison. To the filtrate, 0.5 ml of Sulphuric acid (H_2SO_4, 5 N) and 4 ml of ascorbic acid were added. The solution was then diluted to the mark with distilled water. The intensity of the blue color formed was measured using a colorimeter set to 760 nm, which indicated the phosphorus content.
- **Available Potassium:** Exchangeable potassium was measured using a flame photometer. A 5 g soil sample was mixed with 25 ml of ammonium acetate solution in a 50 ml conical flask. The mixture was agitated for 5 minutes to allow for the extraction of exchangeable potassium. The resulting solution was filtered using Whatman No. 1 filter paper. From the filtrate, a 5 ml aliquot was pipetted into a 25 ml volumetric flask. Standard potassium solutions with concentrations.ranging from 0 to 10 ppm were prepared to calibrate the instrument.

- **Available Sulphur:** The turbidimetric method, as outlined by Chesnin and Yien (1950), was employed to determine available sulphur in soil. Two grams of soil were extracted with 20 ml of 0.15 M sodium acetate buffer (pH 4.8) by shaking for 30 minutes. The mixture was then filtered through Whatman No. 1 filter paper. To the resulting filtrate, 10 ml of 0.25 M barium chloride solution was added, causing the precipitation of barium sulphate ($BaSO_4$). The solution was gently mixed and allowed to stand for 15-30 minutes for complete precipitation. Turbidity was measured using a spectrophotometer at 420 nm, and the concentration of sulphate ions was determined by comparing the sample's turbidity to a calibration curve prepared from standard sulphur solutions.
- **Available zinc:** The DTPA extractable method, as described by Lindsay and Norvell (1978), was used.. Ten grams of air-dried soil, sieved through a 2 mm mesh, were weighed into a 50 ml plastic or glass centrifuge tube. A 20 ml aliquot of DTPA solution (pH 7.3) was added to the soil to extract readily available zinc along with other micronutrients such as copper, manganese, and iron. The mixture was shaken for 2 hours at room temperature (~25°C) using a mechanical shaker to eNSure thorough extraction. The zinc concentration in the filtrate was measured using an atomic absorption spectrophotometer (AAS) or Inductively Coupled Plasma (ICP) spectrometer. Standard zinc solutions were used to prepare a calibration curve, and the zinc concentration in the soil sample was determined by comparing the sample's absorbance to the calibration curve.

Table 3.2: This structure outlines the components of a mechanical analysis used for evaluating soil texture.

S No. Particulars	Contents	Evaluation method
A. (Mechanical analysis)		
i.(Sand %)	67.0	International Pipette Method (Piper, 1950)
ii.(Silt %)	21.5	
iii.(Clay Content)	11.5	USDA hand book-60 (Richards, 1954)
iv.Texture class	Sandy loam	
B. Physical analysis		
i.Bulk density	1.35	Undisturbed Soil Coring (Blake & Hartge, 1986)
ii.Particle density	2.60	USDA Method 33 (Richards, 1954)
iii.Total porosity	48.07	USDA Method 40 (Richards, 1954)
C. Chemical analysis		
i.Organic carbon (%)	0.44	Rapid titration method, (Walkley and black, 1934)
ii.EC (dS m^{-1} at 25^0C)	0.42	EC meter (Jackson, 1973)
iii. pH	7.72	pH meter (Jackson, 1973)
iv.Available nitrogen	205.1 Kg/ha (Low)	Three-part process: digestion, distillation, and titration.
v.Available P_2O_5	33.7 (Medium)	Olsen's method (Olsen et al. 1954)
vi.Available K_2O	222.0 (Medium)	Flame photometer method (Stahlavska 1973)
vii.Available Sulphur	7.62	Turbidimetricmethod (Chesnin and Yien, 1950)
viii.Available Zn	0.44	DTPA Extractable method (Lindsay and Norvell, 1978)

3.5 Cropping History of the Experimental Site

Comprehensive crop history investigations were conducted in the experimental region in previous years. Rapeseed seeds are specifically planted during the Rabi season. The primary aim of this research is to enhance our comprehension of the crop varieties cultivated in the particular area where the research experiments were carried out. This understanding can be valuable in interpreting and deliberating upon the study results. Table 3.3 provides an overview of the crop history

Table 3.3: Cropping History of the Experimental Site

Year	**Crop- Kharif**	**Crop-Rabi**
2019-20	Rice	Barley
2020-21	Maize	Fallow
2021-22	Clusterbean	Barley
2022-23	Fallow	Rapeseed
2023-24	Fallow	Rapeseed*

3.6 Experimental Details

This study used a Factorial Randomized Block Design (FRBD), which included three replications and 10 treatments. Table 3.4 provides information about the treatments and their symbols.

Table 3.4: Details of Experiment

Crop	Gobhi sarson
Variety	GSC-7
Design of Experiment	Factorial Randomized Block Design
Total Treatments	16
Replications	3
Total Plot	48
Plot size	5x4.5
Seed rate	3.75 kg/ha
Spacing	45X10cm

Table 3.5: Treatment Details

Symbols	Treatments	Dose	Source and Time of application
Zinc levels			
Zn_0	Control		
Zn_1	1 application	0.5 g/L	Zinc EDTA 12 % at 15 DAS
Zn_2	2 application	0.5 g/L	Zinc EDTA 12 % at 15 + 45 DAS
Zn_3	3 application	0.5 g/L	Zinc EDTA 12 % at 15 + 45 + 75 DAS
Sulphur levels/(kg S/ha)			
S_0	Control		
S_1	10	10 kg/ha	Bentonite Sulphur 90 % as basal dose
S_2	20	20 kg/ha	Bentonite Sulphur 90 % as basal dose
S_3	30	30 kg/ha	Bentonite Sulphur 90 % as basal dose

3.7: Inputs for the experiment

3.7.1: Varietal Description

GSC-7 is a variety developed by Punjab Agricultural University, Ludhiana, in [2015]. GSC-7 variety contains 40% of oil content. This Variety is matures in almost 154 days or so. This variety requires irrigation 3 times in a season. At the time of sowing, seed treatment is necessary for good growth and better yield. Seeds should be treated with Rhizobium or Fungicides.

3.7.2: Fertilizer application

3.7.2.1: Nitrogen and Phosphorus

The fertilizers required for experimental purpose were received from farm store, of Agronomy Section, Lovely Professional University, Phagwara, Punjab. Nitrogen was applied @100 kg/ha and phosphorus @30 kg/ha. The remaining nitrogen was administered at the time of the first irrigation to support the crop's nutrient uptake.

3.7.2.2: Sulphur

Elemental sulphur was used as source of sulphur containing 90% S in powder form and was applied to rapeseed, treatment wise.

3.7.2.3: Zinc

Zinc (EDTA) was used as source of zinc containing 12% Zn in powder form and was applied to rapeseed as per treatment.

Table 3.6: Specifics of the Cultural Activities Engaged for the Study

Cultural Activities	**Date**	**Date**
Ploughing/planking	29.10.2022	24.10.2023
Layout	04.11.2022	30.11.2023
Sowing	07.11.2022	01.11.2023
a. Fertilizers application	07.11.2022	01.11.2023
b. Top dressing of urea	08.12.2022	09.12.2023
Thinning	16.11.2022	18.11.2023
Weeding		
a. First	04.12.2022	06.12.2023
b. Second	25.12.2022	27.12.2023
Spraying of iNSecticide		
a. First	28.12.2022	23.01.2023
b. Second	20.01.2023	08.02.2024
c. Third	23.02.2023	26.02.2024
Irrigation		
a. First irrigation b. Second irrigation	09.12.2022 20.01.2023	11.12.2023 22.01.2024
Harvesting	09.04.2023	06.04.2024
Threshing	12.04.2023	13.04.2024

3.8 Details of Agronomic Operations

The details of different agronomic operations implemented for the cultivation of crops are outlined below. The chronological record of crop cultivation is presented in Table 3.6.

3.8.1 Field layout

After deep summer ploughing, the experimental plot was harrowed twice, cross wise, with the help of blade harrow to prepare the land for sowing. The stubbles of previous crop were collected and burnt. The field was leveled by a bullock drawn planker and plots as per plan were marked.Finally, the field was divided into uniform plots as per the experimental layout and requirements, eNSuring coNSistency across treatments.

3.8.2 Sowing, seed rate, separation, and sowing procedure

The seed of rapeseed variety GSC-7 was utilized in this study. A seed rate of 3.75 kg/ha, as recommended for mustard, was used. Sowing was done using the drilling method at an optimum soil moisture level.

3.8.3 Weeding and Hoeing

Using a manual tool known as a "khurpi," or "hand hoe," First hoeing along with weeding session was executed out 30 DAS and second weeding at 21days after first weeding to maintain weed-free cultivation conditions in the experimental crop.

3.8.4 Thinning

Thinning was carried out at 15 DAS to ensure proper spacing between plants and achieve the desired plant population for optimal growth.

3.8.5 Irrigation

In addition to the initial pre-sowing irrigation, the rapeseed crop received two crucial supplementary rounds of irrigation to support optimal growth and development. The second round of watering occurred at 65 DAS, coinciding with the flowering stage, which is vital for maximizing the crop's yield potential. This carefully timed irrigation schedule was designed during its most sensitive growth stages, thereby promoting healthy plant development and enhancing overall productivity.

3.8.6 Harvesting

Harvesting was done manually when the crop showed physiological maturity and the seeds were completely matured. Harvesting was done with sickle by cutting the stem at the ground surface. Observational plants were harvested first and were taken to the laboratory for the post-harvest studies. This ensured proper identification and organization of the crop from each treatment group for further analysis. The quantity of produce received from each net plot was weighed and recorded as net plot yield and used for per hectare yield estimation.

3.8.7 Threshing

The harvested plants were bundled together, with bundles from each experimental plot tied individually and left to sun dry for several days. After noting the total weight of each bundle, the seeds were extracted using wooden sticks once the drying period was complete. This process ensured accurate measurement of yield from each experimental plot, allowing for detailed analysis of the crop's performance.

3.9 : Observations Recorded

3.9.1: Plant stand: Total no. of seedlings emerged per square meter from net plot area was counted fifteen day after sowing. Similarly the final plant stand was recorded at the time of harvest and plant stand per net plot was calculated.

3.9.2: Plant height (cm): The height of the main shoot was determined using a meter scale, ensuring accuracy in the measurements. The measurement process involved placing the meter scale at the base of the plant, right at ground level, and extending it vertically up to the tip of the plant's growing point. This approach provided a consistent and reliable method to record the height of the plants for further analysis. Measurements were taken at 30, 60, 90, and 120 (DAS) and at harvest time to monitor growth progression. This process was repeated for the second trial to ensureconsistency and reliability of data.

3.9.3: Fresh weight: The fresh weight of the plants was recorded by removing three plants from each plot using a sickle at 30, 60, 90, and 120 (DAS). The plants were weighed immediately in grams.

3.9.4 Dry matter accumulation per plant: A random selection of five plants was made from the border rows of each plot at four different growth stages: early, mid, late, and at the time of harvest. These plants were carefully uprooted and placed in brown paper bags for proper storage and labelling. The plants were first air-dried in the sun for 3-4 days. Subsequently, they were placed in a hot air oven at 50°C for 36 hours to remove moisture. The average dry matter accumulation was calculated based on the measurements at different stages of crop growth. After drying, the plants were weighed, and observations were recorded.

3.9.5: Number of leaves per plant: Four plants were randomly selected and tagged in each plot for observation. The number of leaves per plant was counted 30, 60, 90, and 120 days after sowing (DAS) as well as at harvest time.

3.9.6: Number of branches per plant: The statement describes a method to assess branch development in plants by counting the number of branches arising from the main stem at different growth stages. The average quantity of branches for each plant is then calculated by dividing the total number of branches counted on the sample plants by the number of plants, giving a representative measure of branch production at each time point. This method helps monitor the plant's growth and provides insights into its development over time.

3.9.7: Number of siliquae/plant: To determine the average number of siliquae/ plant, mature siliquae were counted from five plants chosen at random. The number of siliquae from these plants was then added together, and the sum was divided by the number of plants.

3.9.8: Seed yield per plant (g): From each net plot, five sample plants were harvested and dried individually. The seeds were separated and weighed to record seed yield per plant.

3.9.9: Straw yield per plant: From each net plot, five sample plants were harvested and dried individually. The straw was separated and weighed to record straw yield plant^{-1}.

3.9.10: Number of seed per siliqua; From each net plot, five sample plants were harvested and dried individually. From each observation plant five siliqua were collected, threshed and number of seed siliqua-1 were counted out.

3.9.11: Length of siliqua: From each net plot, five sample plants were harvested and dried individually. The length of five siliqua was measured and average was worked out.

3.9.12: Seed yield (kg/ha): Each net plot was harvested individually, with the plants gathered and tied into bundles. These bundles were then placed upright. After the drying process, the seeds were carefully separated from the plants. Once the seeds were fully separated, they were cleaned to remove any debris or unwanted material. Finally, the weight of the cleaned seeds from each net plot was measured using a weighing balance to determine the seed yield.

3.9.13: Straw yield (kg/ha): The straw yield was measured to record by subtracting the weight of the grains from the total weight of the harvested plant. The straw weight was then expressed as the yield in kilograms per hectare after the straw was fully dried.

3.9.14: Harvest index

The harvest index was determined employing the formula below:

$$\text{Harvest index (\%)} = (\text{Economical yield (kg/ha)} / \text{Biological yield (kg/ha)}) \times 100$$

3.9.15: Initial soil status

The soil from these spots was thoroughly mixed, and then 500 g of soil was taken using the quartering method. This sample was air-dried, ground using a mechanical grinder, and stored in a cloth bag for further chemical analysis of the initial available nutrients.

3.9.16: Residual nutrient status of soil

Residual were collected from each net plot, thoroughly dried, ground using a mechanical grinder, and then used for chemical analysis. The Sulphur content in both seed and plant samples was determined using the Barium Sulfate Turbidimetry method.

3.9.17: Total sulphur uptake by plant:

Representative seed and plant samples were collected from each net plot, thoroughly dried, ground using a mechanical grinder, and then used for chemical analysis.

$$\text{Total sulphur uptake by seed (kg/ha)} = \frac{\text{Seed yield (kg/ha)} \quad \text{Sulphur content in seed (\%)}}{100}$$

$$\text{Total sulphur uptake by straw (kg/ha)} = \frac{\text{Straw yield (kg/ha)} \quad \text{Sulphur content in straw (\%)}}{100}$$

3.9.18: Total zinc uptake by plant:

These samples were subsequently subjected to thorough drying to ensure they were prepared appropriately for further analysis and storage. After drying, the samples were ground using a mechanical grinder for chemical analysis. The zinc content in both the seed and plant samples was determined using the DTPA extraction method.

Total zinc uptake = Zinc uptake by seed + Zinc uptake by straw

Zinc uptake by seed (g/ha) = Seed yield (t/ha) Zinc content in seed (ppm)

Zinc uptake by straw (g/ha) = Straw yield (t/ha) Zinc content in straw (ppm)

3.10 Quality parameters

3.10.1 Protein content in seed (%) and protein yield (kg/ha)

This was determined by first measuring the nitrogen content and then multiplying it by a factor of 6.25. Using the percentage of protein and the total seed yield, the amount of protein produced per hectare was calculated.

$$\text{Protein yield (kg/ha)} = \frac{\text{Seed yield (kg/ha)} \times \text{Protein content (\%)}}{100}$$

3.10.2 Oil content in seed (%) and oil yield (kg/ha)

This is determined using the Soxhlet ether extraction method, as described by Sankaran in 1966. This method involves using a solvent (ether) to extract the oil from the seed samples. The percentage of oil in the seeds was then calculated using a specific formula based on the amount of oil extracted from the seeds.

$$\text{Oil (\%)} = \frac{\text{Weight of oil}}{\text{Weight of sample}} \times 100$$

This was done by multiplying the percentage of oil by the total seed yield per hectare. This calculation provided the total oil yield produced per unit area of land.

$$\text{Oil yield (kg/ha)} = \frac{\text{Seed yield (kg/ha)} \times \text{Oil content (\%)}}{100}$$

3.11 Economic analysis

3.11.1 Cultivation Cost (Rs/ha)

This was calculated for each experimental condition, considering the current expenses associated with agricultural practices, including labour costs, and the market value of the inputs used.

3.11.2 Net returns (Rs/ha)

To calculate the net returns per hectare for each treatment, the total costs of cultivation were subtracted from the gross revenue generated by that treatment. This gave a clear measure of the profit obtained from each specific treatment after covering all related expenses.

3.11.3 Gross Returns (Rs/ha)

Gross returns were calculated by evaluating the revenue generated from both seed and stover yields of gobhi sarson obtained from various experimental treatments. This calculation was based on the market prices that were current during the year of the experiment, providing an accurate reflection of potential income.

3.11.4 Benefit cost ratio (B: C ratio)

The Net profits had to be divided by the total expenses to calculate each treatment associated with that treatment using the following formula:

Benefit cost ratio (%) = (Net returns (Rs/ha) / Total cost of cultivation (Rs/ha)) × 100

3.12 Statistical analysis

The experimental data measured throughout the investigation were analyzed using a factorial randomized block design, applying standard statistical methods. Whenever, the results were significant, critical difference at P=0.05 level were calculated for comparison of treatment means. Data on interaction effects are presented whenever found significant. The data on treatment effects are presented suitably in appropriate tables and illustrated graphically at appropriate places.

3.7 Analysis of variance for gobhi sarson

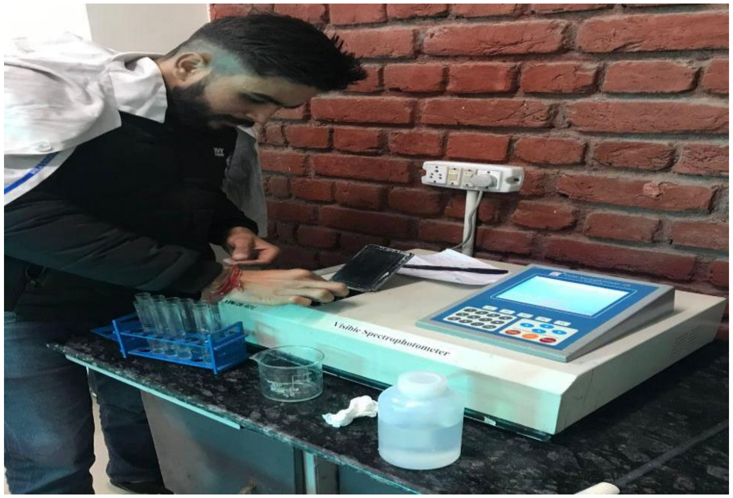
Source of variation	**Degree of freedom**	**Sum of square**	**Mean sum of square**	**F_{cal}**	**F_{tab}**
Sulphur (a)	(a-1) = 3				
Zinc spray (b)	(b-1) = 3				
Interaction (a x b)	(a-1) (b-1) = 9				
Replication	(r-1) = 2				
Error	(r-1) (ab-1) = 30				
Total	(rab – 1) = 47				

3.13 Demonstration

Field view after sowing Gobhi Sarson (Brassica napus L.)

Preparation of field layout for experimental plots

Collecting data from Gobhi Sarson plants in the field



Recording spectrometer readings for sample analysis

Applying insecticide spray in the Gobhi Sarson field

Collecting plant samples from the field

Measuring chlorophyll content in the laboratory

Gobhi Sarson crop at the flowering stage

Chapter-4

EXPERIMENTAL RESULT AND DISCUSSION

The findings of the field experiment titled "Effect of Different Levels of Sulphur and Zinc on Growth, Yield, and Quality Attributes of Gobhi Sarson (*Brassica napus* L.)" conducted at the Agronomy Farm of Lovely Professional University (LPU), Punjab, during the consecutive Rabi seasons of 2022-2023 and 2023-2024 are presented in this chapter. The outcomes highlight that all observed effects were significant when analyzed through pooled data. Data analysis is being presented in succeeding in table 4.1 to 4.30 and fig. 4.1 to 4.9.

4.1 Growth parameters include

Table (4.1 to 4.5) show data on the height of the plant, both fresh and dried weight, the quantity of leaves per plant, chlorophyll content and main and secondary leaf counts.

4.1.1 Plant height

The treatment involving the highest sulphur application rate (S_3 – 30 kg/ha) recorded the tallest plants at all growth stages compared to the untreated control (S_0), with values progressively increasing from 13.16 cm at 30 DAS to 174.62 cm at harvest (pooled data). In contrast, the control treatment (S_0) recorded the lowest plant heights across all stages, ranging from 10.46 cm at 30 DAS to 136.62 cm at harvest. A noticeable improvement in plant height was also observed with medium sulphur application (S_2 – 20 kg/ha), which reached 12.41 cm at 30 DAS and 170.75 cm at harvest. These results indicate a substantial increase of approximately 38.00 cm at harvest between the highest sulphur dose (S_3) and the control (S_0). The increase in plant height with higher sulphur application can be attributed to sulphur's crucial role in cell division, elongation, and chlorophyll synthesis, which collectively enhance photosynthesis and overall vegetative growth.

Zinc application

A thorough analysis of the data exposes that the application of zinc had a marked impact on the height of gobhi sarson plants at various stages of growth—early, mid, late, and at maturity, as well as at harvest. The tallest plants were consistently observed with the highest level of zinc application, which outperformed other zinc treatments but was statistically similar to the second-highest level of zinc application. The increase in plant height with the most substantial zinc treatment showed a clear advantage over the untreated control.

Zinc application also significantly influenced plant height. The highest plant height at harvest was recorded under the treatment with three foliar applications of zinc (Z_3), with a pooled height of 178.31 cm, compared to 137.80 cm under the control (Z_0). Intermediate values were observed for one and two applications (Z_1 – 153.20 cm and Z_2– 167.54 cm, respectively), demonstrating a consistent increase in height with increasing zinc applications.

4.1.2 Fresh weight per plant

Sulphur levels

The information in the table illustrates that the fresh weight of gobhi sarson was notably affected by increasing levels of sulphur at various stages. On an average basis, the highest sulphur application rate (30kg/ha) demonstrated a significant boost in fresh weight compared to the lower sulphur levels, although it was statistically comparable to the 20 kg/ha treatment in some stages. The highest level of sulphur application resulted in considerable increases in fresh weight at early (30 DAS), mid (60 DAS), late (90 DAS), and maturity (120 DAS) stages, as well as at harvest. For instance, at 120 DAS, the fresh weight increased to 669.20 g/plant and 672.45 g/plant in 2022–23 and 2023–24 respectively under the S_3 treatment, resulting in a pooled mean of 670.83 g/plant, significantly higher than the control. This indicates that adequate sulphur supplementation plays a crucial role in enhancing vegetative biomass accumulation, leading to better growth performance across all measured periods.

Zinc application

Three foliar applications of zinc (Zn_3) were found statistically at par with two applications (Zn_2), recording the maximum fresh weight per plant of Gobhi Sarson throughout all the growth stages when compared to the control (Zn_0). The increase in fresh weight due to Zn_3 treatment was particularly evident at 30, 60, 90, and 120 DAS, and at harvest. Fresh weight of mustard increased due to three foliar applications of zinc (Zn_3) to the tune of 20.05%, 39.30%, 28.77%, 43.52%, and 27.95% over the control (Zn_0), respectively. For instance, at 90 DAS, Zn_3 resulted in a pooled fresh weight of 382.37 g/plant, compared to 296.95

g/plant **u**nder Zn_0. This enhancement can be attributed to the role of zinc in improving metabolic activity, auxin production, and photosynthetic efficiency, thereby contributing to better biomass accumulation.

Interaction Effect (S × Zn)

The interaction between sulphur and zinc applications on fresh weight was found to be non-significant at all the growth stages and at harvest. However, the combined effects of higher sulphur and zinc levels individually contributed to notable improvements in fresh biomass accumulation, confirming the synergistic role of these nutrients in enhancing crop vigor and productivity.

Table 4.1: Effect of sulphur levels and zinc application on plant height at different growth stages of gobhi sarson

Treatments	Plant height (cm)														
	(30 DAS)			(60 DAS)			(90 DAS)			(120DAS)			at harvest		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Sulphur levels															
S_0-Control	10.42	10.49	10.46	43.49	43.59	43.54	116.92	117.41	117.17	131.14	132.14	131.64	136.10	137.13	136.62
S_1-10 kg/ha	11.52	11.61	11.57	45.72	45.92	45.82	127.16	128.06	127.61	142.00	142.92	142.46	154.28	155.47	154.88
S_2-20 kg/ha	12.39	12.42	12.41	47.88	48.23	48.06	135.62	136.52	136.07	151.49	152.36	151.93	170.15	171.35	170.75
S_3-30 kg/ha	13.10	13.22	13.16	48.07	48.39	48.23	136.98	138.45	137.72	155.13	156.24	155.69	174.12	175.12	174.62
SEm$\pm$	0.22	0.27	0.17	0.75	0.79	0.54	2.47	2.59	1.79	2.98	3.05	2.13	3.38	3.66	2.49
CD (P=0.05)	0.62	0.79	0.49	2.15	2.27	1.53	7.13	7.47	5.06	8.61	8.81	6.03	9.76	10.57	7.05
Zinc application															
Z_0-Control	10.50	10.62	10.56	42.95	43.26	43.10	113.01	113.81	113.41	128.48	129.62	129.05	137.44	138.16	137.80
Z_1-1 appl.	11.64	11.69	11.67	45.25	45.43	45.34	125.04	126.02	125.53	139.84	140.99	140.42	152.82	153.59	153.20
Z_2-2 appl.	12.43	12.50	12.47	47.41	47.69	47.55	135.02	136.28	135.65	150.71	151.71	151.21	166.96	168.12	167.54
Z_3-3 appl.	12.86	12.92	12.89	49.54	49.75	49.65	143.61	144.33	143.97	160.74	161.34	161.04	177.43	179.19	178.31
SEm$\pm$	0.22	0.27	0.17	0.75	0.79	0.54	2.47	2.59	1.79	2.98	3.05	2.13	3.38	3.66	2.49
CD (P=0.05)	0.62	0.79	0.49	2.15	2.27	1.53	7.13	7.47	5.06	8.61	8.81	6.03	9.76	10.57	7.05
CV (%)	7.90	9.88	7.16	6.98	7.31	5.72	8.27	8.61	6.75	8.91	9.05	7.18	9.22	9.92	7.66
Interaction SxZn															
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.1.3 Dry weight (g)

Sulphur levels

An examination of the data in the referenced tables highlights a noticeable increase in the dry weight of gobhi sarson with varying levels of sulphur application. The combined results over the two study years showed that the highest sulphur level led to the greatest dry weight per plant when compared to the control treatment. This high sulphur application produced a marked improvement in dry weight at all measured growth stages—from early growth through to harvest—showing significant gains over the untreated control.The treatment with the highest sulphur level was closely followed by the moderate level and then the lowest level of sulphur application, each contributing progressively less to dry weight but still showing enhancements over the control. This chain of positive effects contributes to increased dry matter production. The findings align with research by (Piri and Sharma, 2011), as well as (Singh and Dhiman, 2005), who reported higher dry matter accumulation with increased sulphur levels.

Zinc application

The experimental results, as outlined in the table, indicate that zinc application notably enhanced the dry weight of gobhi sarson throughout all growth stages when compared to the control. The treatment with three zinc application was found to be comparable to the treatment with two application, both showing significant improvements in dry weight at various stages of growth—(30, 60, 90, and 120) DAS, as well as at harvest. Specifically, the dry weight of the plants increased substantially with three zinc application compared to the control and one application, with the greatest gaiNS observed early in the growth cycle and continuing through to harvest. This improvement in dry weight is likely due to the higher amount of branches and increased plant height resulting from the zinc application. These findings are consistent with previous research by Kaur et al., which also reported an increase in mustard dry matter following the application of zinc. However, a closer examination of the zinc did not lead to a significant interaction that would further influence the dry weight at any of the growth stages.

Table 4.2: Impactof sulphur levels and zinc application on fresh weight at different stages of gobhi sarson

Treatments	Fresh weight (gm/plant)														
	(30 DAS)			(60 DAS)			(90 DAS)			(120 DAS)			At harvest		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Zinc application															
Z_0-Control	3.77	3.81	3.79	86.19	86.66	86.42	295.84	298.07	296.95	439.90	445.87	442.88	325.34	327.54	326.44
Z_1-1 appl.	4.16	4.22	4.19	102.13	102.91	102.52	339.39	338.49	338.94	527.45	530.41	528.93	374.43	376.87	375.65
Z_2-2 appl.	4.41	4.48	4.45	115.87	116.70	116.29	375.85	379.03	377.44	611.28	615.75	613.51	407.66	409.27	408.46
Z_3-3 appl.	4.51	4.59	4.55	119.94	120.82	120.38	381.90	382.84	382.37	635.75	635.48	635.62	416.91	418.47	417.69
SEm±	0.07	0.07	0.05	2.33	2.52	1.72	7.36	7.64	5.30	12.50	12.95	9.00	7.58	7.95	5.49
CD (P=0.05)	0.20	0.22	0.14	6.73	7.29	4.86	21.25	22.05	15.00	36.10	37.40	25.46	21.88	22.97	15.54
Sulphur levels															
S_0-Control	3.71	3.76	3.74	86.12	86.62	86.37	291.45	293.62	292.54	428.13	431.24	429.69	322.24	324.12	323.18
S_1-10 kg/ha	4.15	4.21	4.18	100.14	101.12	100.63	335.91	337.45	336.68	515.63	518.44	517.04	368.12	370.25	369.19
S_2-20 kg/ha	4.39	4.45	4.42	113.24	114.05	113.65	370.15	371.00	370.58	601.42	605.38	603.40	402.13	404.19	403.16
S_3-30 kg/ha	4.61	4.68	4.65	124.63	125.30	124.97	395.47	396.36	395.92	669.20	672.45	670.83	431.85	433.58	432.72
SEm±	0.07	0.07	0.05	2.33	2.52	1.72	7.36	7.64	5.30	12.50	12.95	9.00	7.58	7.95	5.49
CD (P=0.05)	0.20	0.22	0.14	6.73	7.29	4.86	21.25	22.05	15.00	36.10	37.40	25.46	21.88	22.97	15.54
CV (%)	6.94	7.55	5.81	9.52	10.24	7.91	9.15	9.46	7.44	9.78	10.07	7.94	8.61	8.99	7.04
Interaction SxZn															
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.3 Impact of sulphur levels and zinc application on dry weight at different stages of gobhi sarson

Treatments	Dry weight (gm/plant)														
	30 DAYS			60 DAYS			90 DAYS			120 DAYS			At harvest		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Sulphur levels															
S_0-Control	0.59	0.61	0.60	11.87	12.00	11.94	31.32	32.13	31.73	42.21	42.36	42.29	46.59	46.75	46.67
S_1-10 kg/ha	0.67	0.69	0.68	13.15	13.36	13.26	33.79	34.66	34.23	47.10	47.65	47.38	50.42	50.72	50.57
S_2-20 kg/ha	0.73	0.75	0.74	14.32	14.45	14.39	36.10	36.98	36.54	50.51	51.00	50.76	53.65	53.86	53.76
S_3-30 kg/ha	0.78	0.79	0.79	15.10	15.32	15.21	38.39	39.48	38.94	53.66	54.16	53.91	56.62	56.89	56.76
SEm±	0.01	0.01	0.01	0.25	0.27	0.18	0.79	0.86	0.58	0.86	1.03	0.67	1.02	1.04	0.73
CD (P=0.05)	0.04	0.04	0.03	0.73	0.78	0.52	2.28	2.48	1.65	2.49	2.96	1.90	2.95	3.01	2.07
Zinc application															
Z_0-Control	0.59	0.62	0.60	11.82	11.90	11.86	31.82	33.27	32.55	42.83	42.99	42.91	46.48	46.70	46.59
Z_1-1 appl.	0.68	0.70	0.69	13.62	13.76	13.69	34.23	35.37	34.80	47.68	47.89	47.78	51.20	51.31	51.26
Z_2-2 appl.	0.74	0.75	0.75	14.43	14.67	14.55	36.59	37.20	36.89	51.03	51.76	51.39	54.18	54.46	54.32
Z_3-3 appl.	0.76	0.77	0.77	14.58	14.80	14.69	36.96	37.41	37.19	51.94	52.54	52.24	55.42	55.74	55.58
SEm±	0.01	0.01	0.01	0.25	0.27	0.18	0.79	0.86	0.58	0.86	1.03	0.67	1.02	1.04	0.73
CD (P=0.05)	0.04	0.04	0.03	0.73	0.78	0.52	2.28	2.48	1.65	2.49	2.96	1.90	2.95	3.01	2.07
CV (%)	8.00	7.80	6.32	8.01	8.44	6.58	9.78	10.37	8.07	7.72	9.10	6.76	8.54	8.67	6.89
Interaction SxZn															
CD (P=0.05)	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.	NS.

4.1.4: Number of leaves/plant

Sulphur levels

Among the different sulphur treatments, the highest leaf count/Plant was observed with the application of a higher sulphur dose (S_3-30kg/ha), which considerably outperformed the control treatment. The highest leaf count was recorded with the highest level of sulphur fertilization, followed by the moderate and lower levels of sulphur application. At 120 DAS, the pooled leaf count under S_3 was 37.55, compared to 30.43 under the control. The observed increase in leaf number due to the highest sulphur treatment can be attributed to the beneficial role of sulphur in promoting leaf development. The results align with previous studies by (Negi and Kaur, 2017) who also reported similar findings regarding the positive impact of sulphur on leaf development in gobhi sarson.

Zinc application

The data presented in the experiment show that the number of leaves per plant in ***Gobhi Sarson*** was notably influenced by the application of zinc at various growth stages. At 120 DAS, the pooled number of leaves per plant in the treatment with three zinc applications (Z_3) was 36.84, significantly higher than the control (Z_0), which had 30.78. The treatment involving three applications of zinc (Z_3) was similar in effect to the two-application treatment (Z_2, 35.90 leaves), but still resulted in the highest leaf count. The enhanced leaf development observed with multiple zinc applications can be attributed to the beneficial effects of zinc in supporting plant growth, particularly in processes that contribute to leaf formation.

Table 4.4: Impact of sulphur levels and Zn application leaf per plant at different stages of Gobhi sarson

Treatments	Number of leaf per plant											
	30 DAS			60 DAS			90 DAS			120 DAS		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Sulphur levels												
S_0-Control	4.15	4.19	4.17	17.65	17.84	17.75	25.59	25.96	25.78	30.35	30.51	30.43
S_1-10 kg/ha	4.69	4.75	4.72	18.85	18.91	18.88	27.35	27.66	27.51	33.10	33.37	33.24
S_2-20 kg/ha	5.21	5.26	5.24	19.82	19.96	19.89	28.92	29.29	29.11	35.46	35.76	35.61
S_3-30 kg/ha	5.25	5.30	5.28	20.77	20.95	20.86	30.43	30.81	30.62	37.39	37.71	37.55
SEm±	0.11	0.13	0.09	0.32	0.34	0.23	0.51	0.56	0.38	0.63	0.66	0.46
CD (P=0.05)	0.32	0.38	0.24	0.94	0.97	0.66	1.48	1.63	1.08	1.83	1.92	1.30
Zinc application												
Z_0-Control	4.09	4.14	4.11	17.59	17.67	17.63	25.83	26.06	25.94	30.64	30.92	30.78
Z_1-1 appl.	4.64	4.70	4.67	19.08	19.28	19.18	27.67	28.01	27.84	33.23	33.39	33.31
Z_2-2 appl.	5.08	5.12	5.10	20.03	20.20	20.11	29.29	29.74	29.51	35.74	36.06	35.90
Z_3-3 appl.	5.49	5.54	5.52	20.38	20.51	20.44	29.50	29.91	29.71	36.69	36.98	36.84
SEm±	0.11	0.13	0.09	0.32	0.34	0.23	0.51	0.56	0.38	0.63	0.66	0.46
CD (P=0.05)	0.32	0.38	0.24	0.94	0.97	0.66	1.48	1.63	1.08	1.83	1.92	1.30
CV (%)	9.86	11.70	8.67	7.30	7.49	5.92	7.91	8.57	6.60	8.04	8.38	6.57
Interaction SxZn												
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.1.5: Chlorophyll content

Sulphur levels

Application of varying sulphur levels significantly influenced the chlorophyll content in gobhi sarson. On a pooled mean basis, the highest chlorophyll content (2.62 mg/g) was recorded with the application of sulphur at 30 kg/ha (S_3), followed by 2.52 mg/g under 20 kg/ha sulphur (S_2). In contrast, the control treatment (S0) recorded the lowest chlorophyll content (2.24 mg/g). This progressive increase in chlorophyll content with increasing sulphur levels reflects the essential role of sulphur in chlorophyll biosynthesis and overall plant metabolism (Table 4.5).

Zinc application

Similarly, chlorophyll content was positively influenced by zinc application. The pooled data revealed a significant increase in chlorophyll content under three zinc applications (Zn_3), which recorded the maximum value of 2.55 mg/g. This was statistically at par with Zn2 (2.52 mg/g), while the lowest value was observed under the control (Zn_0) with 2.29 mg/g. The results underline the importance of adequate zinc supply in maintaining chlorophyll levels and enhancing photosynthetic efficiency. Although numerical differences were noted, a detailed statistical analysis of Table 4.5 indicates that the interaction between sulphur and zinc applications did not result in a significant combined effect on chlorophyll content across both years and pooled data.

4.1.6: The total number of primary branches in each plant:

Sulphur levels

On a pooled mean basis, the highest number of primary branches per plant (5.26) was observed with the application of sulphur at 30 kg/ha (S_3), which was significantly higher than that recorded under the control (4.08) and sulphur at 10 kg/ha (S_1) (4.51). However, this value was statistically at par with the treatment receiving 20 kg/ha sulphur (S_2), which recorded 4.92 branches per plant. The increase in the number of primary branches under S_3 corresponded to an enhancement of 28.92% and 9.62% over the control and S_1 treatments, respectively. These findings suggest that increasing sulphur availability promotes better vegetative branching, likely due to improved metabolic activity and auxin synthesis.

Zinc application

Among the zinc treatments, the application of zinc thrice (Zn_3) resulted in the maximum number of primary branches per plant (5.06), which was statistically at par with Zn_2 (4.95), and significantly superior to Zn_1 (4.59) and the control (Zn_0) (4.16). The increase under Zn_3 was 21.63% over Zn_0 and 10.24% over Zn_1, indicating a clear benefit of repeated zinc application in promoting shoot proliferation. Enhanced zinc availability may have supported improved meristematic activity and hormone regulation, leading to increased branching.

Although individual effects of sulphur and zinc were statistically significant, the interaction between the two did not show a notable influence on the number of primary branches per plant, as reported in Table 4.5.

4.1.7: The total number of secondary branches in each plant

Sulphur levels

On a pooled mean basis, the application of sulphur at 30 kg/ha (S_3) resulted in the maximum number of secondary branches per plant (16.40), which was significantly higher than the control (S_0) at 13.58 and sulphur at 10 kg/ha (S_1) at 14.89. However, the number under S_3 was statistically at par with the 20 kg/ha treatment (S_2), which recorded 15.74 branches per plant. This increasing trend in secondary branches with rising sulphur levels confirms the positive influence of sulphur on the branching ability of gobhi sarson. The observed improvements support the findings of Tomar et al., who emphasized sulphur's essential role in enhancing vegetative growth and branch development.

Zinc application

Among the zinc treatments, the highest number of secondary branches per plant was recorded with three zinc applications (Zn_3), registering a pooled mean of 16.15 branches, which was statistically comparable to Zn_2 (15.93). Both were significantly superior to Zn_1 (14.94) and the control Zn_0 (13.58). This enhancement aligns with previous findings by Kumar et al. (2014) and Jat et al. (2012), who reported increased branching with higher zinc supplementation.

The positive effect of zinc may be attributed to its role in improving cellular function and auxin metabolism, while the increase in branching under sulphur treatments could be linked to enhanced protein and amino acid synthesis, which facilitates active cell division and meristematic activity. Although a combination of sulphur and zinc improved individual plant growth traits, the interaction effect (S × Zn) was statistically non-significant for the number of secondary branches (Table 4.5).

The additional influence of soil amendments like hydrogel, known for their water retention properties, may further improve nutrient uptake and root zone moisture availability (Sahu et al., 1993; Anupama et al., 2005), indirectly supporting branch proliferation and overall plant vigour.

Table 4.5: Impact of sulphur levels and zinc application on Chlorophyll content at 60 DAS, Number of primary branches and secondary branches per plant of gobhi sarson

Treatments	**Chlorophyll content (mg/g)**			**Number of primary branches per plant**			**Number of secondary branches per plant**		
	2022-23	**2023-24**	**Pooled**	**2022-23**	**2023-24**	**Pooled**	**2022-23**	**2023-24**	**Pooled**
Sulphur levels									
S_0-Control	2.21	2.27	2.24	4.07	4.09	4.08	13.55	13.61	13.58
S_1-10 kg/ha	2.37	2.40	2.39	4.48	4.53	4.51	14.81	14.96	14.89
S_2-20 kg/ha	2.51	2.53	2.52	4.88	4.96	4.92	15.68	15.79	15.74
S_3-30 kg/ha	2.61	2.62	2.62	5.21	5.31	5.26	16.35	16.45	16.40
SEm$\pm$	0.03	0.03	0.02	0.09	0.08	0.06	0.28	0.28	0.20
CD (P=0.05)	0.09	0.10	0.07	0.26	0.23	0.17	0.81	0.80	0.56
Zinc application									
Z_0-Control	2.27	2.30	2.29	4.14	4.18	4.16	13.54	13.61	13.58
Z_1-1 appl.	2.40	2.43	2.41	4.55	4.62	4.59	14.88	15.01	14.94
Z_2-2 appl.	2.50	2.53	2.52	4.92	4.98	4.95	15.84	16.02	15.93
Z_3-3 appl.	2.53	2.56	2.55	5.02	5.10	5.06	16.13	16.18	16.15
SEm$\pm$	0.03	0.03	0.02	0.09	0.08	0.06	0.28	0.28	0.20
CD (P=0.05)	0.09	0.10	0.07	0.26	0.23	0.17	0.81	0.80	0.56
CV (%)	5.80	5.85	4.66	8.52	7.24	6.32	8.03	7.87	6.36
Interaction SxZn									
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.1.8 Leaf area index

Sulphur levels

The application of sulphur at varying levels had a notable influence on the leaf area index (LAI) of gobhi sarson. On a pooled mean basis, the highest LAI (6.51) was recorded with sulphur applied at 30 kg/ha (S3), followed by 6.23 under 20 kg/ha (S_2), and 5.94 under 10 kg/ha (S_1). The lowest LAI (5.64) was observed in the control treatment (S_0). The increase in LAI under S_3 was 15.43% and 9.60% higher than the control (S_0) and S_1, respectively. This upward trend indicates that sulphur application enhances leaf expansion and canopy development, likely due to its role in chlorophyll synthesis and protein metabolism, leading to better vegetative growth and photosynthetic surface area.

Zinc application

Zinc treatments also demonstrated a significant impact on LAI. The pooled mean data revealed that the maximum LAI (6.39) was recorded with three applications of zinc (Zn_3), which was statistically at par with Zn_2 (6.35), and significantly higher than Zn_1 (5.98) and the control (Zn_0) (5.59). The increase in LAI under Zn_3 was 14.31% and 6.86% greater than Zn_0 and Zn_1, respectively. This result suggests that multiple zinc applications enhance the leaf surface area, potentially due to improved enzymatic activity and hormonal balance, which favor cell division and expansion in leaf tissues.Although both sulphur and zinc individually influenced the LAI significantly, the interaction between the two treatments (S × Zn) was found to be statistically non-significant, as indicated in Table 4.6.

4.2: Yield attributes and yield

4.2.1 Number of siliqua per plant

Sulphur levels

Table 4.7 indicates that the highest sulphur application level markedly increased the number of siliqua per plant in Gobhi Sarson when compared to both the untreated control and the treatments with lower sulphur levels. This trend was consistent across all experimental years and reflected in the overall mean data. The pooled analysis further confirmed that the maximum sulphur application notably enhanced the number of siliquae compared to the control and lower sulphur levels. This improvement is likely attributed to the increased overall biomass production and the effective translocation of nutrients to various parts of the plant, which in turn enhanced the yield attributes. These results align with earlier findings by Verma et al. (2011), who reported similar results outcomeswith higher sulphur application.

Table 4.6:Impact of sulphur levels and zinc application on leaf area index of gobhi sarson

Treatments	**LAI**		
Sulphur levels	**2022-23**	**2023-24**	**Pooled**
S_0-Control	5.62	5.66	5.64
S_1-10 kg/ha	5.91	5.97	5.94
S_2-20 kg/ha	6.19	6.27	6.23
S_3-30 kg/ha	6.45	6.56	6.51
SEm±	0.09	0.10	0.07
CD (P=0.05)	0.26	0.29	0.19
Zinc application			
Z_0-Control	5.56	5.63	5.59
Z_1-1 appl.	5.95	6.02	5.98
Z_2-2 appl.	6.30	6.39	6.35
Z_3-3 appl.	6.36	6.42	6.39
SEm±	0.09	0.10	0.07
CD (P=0.05)	0.26	0.29	0.19
CV (%)	6.46	7.05	5.41
Interaction SxZn			
CD (P=0.05)	NS	NS	NS

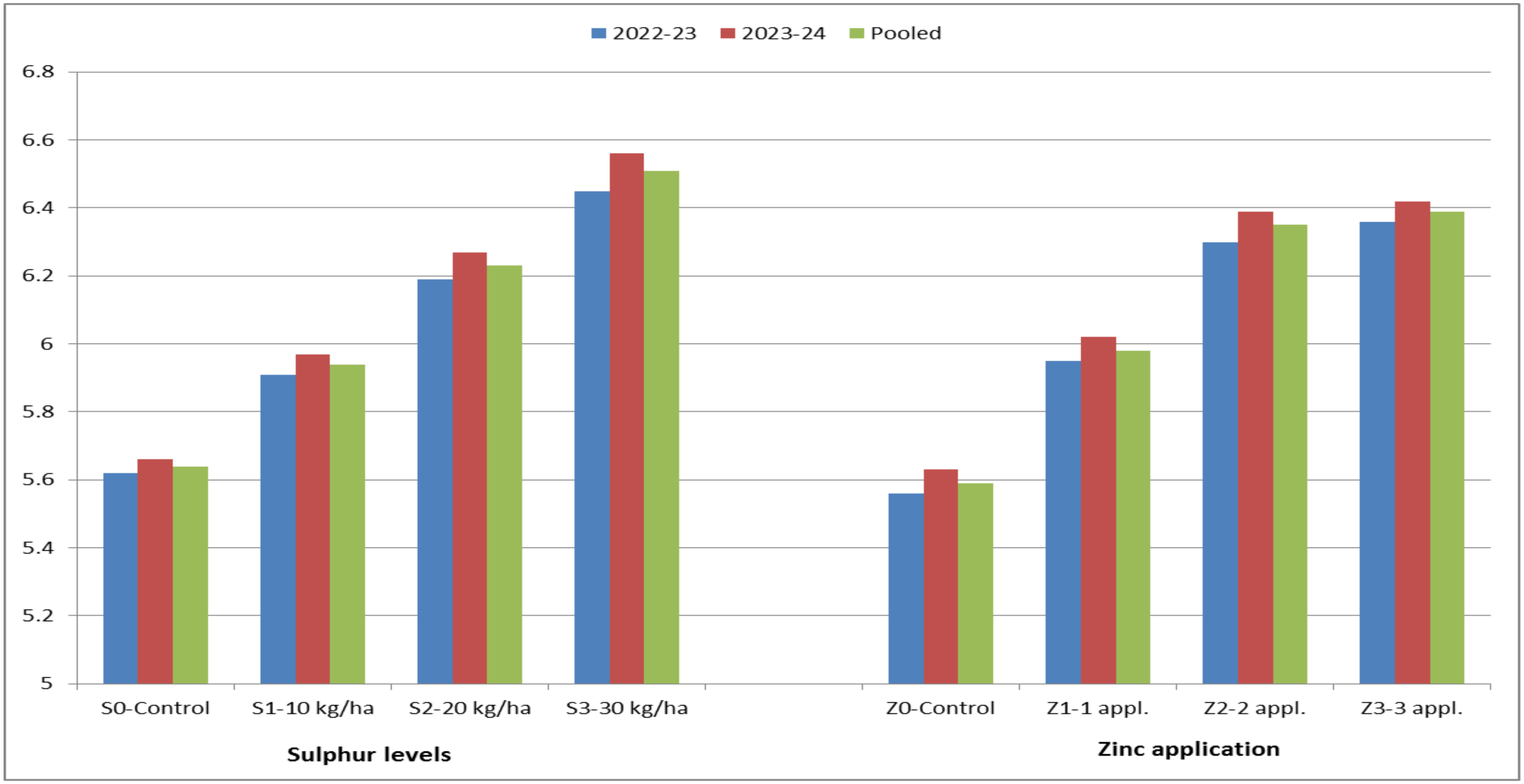


Fig. 4.1: Effect of sulphur levels and zince application on leaf area index of gobhi sarson.

Zinc application

A thorough review of the data in Table 4.7 reveals that the usage of zinc considerably enhanced the number of siliquae/plant of Gobhi Sarson in both experimental years, as well as in the combined analysis. The highest number of siliquae per plant was achieved with three zinc applications.(Zn_3), which outperformed the other treatments. The three zinc sprays led to a marked increase in the number of siliquae compared to the control, with improvements observed across both years and in the pooled data. This increase is likely due to the optimal availability of zinc, which may have contributed to a more balanced nutrient profile for the plants. Similar results were noted in the work of Kaur et al. (2017). Additionally, the interaction between Sulphur levels and zinc application did not show any major impact on the number of siliqua/plant of Gobhi Sarson, as evidenced by the data in Table 4.7.

The number of siliquae per plant increased significantly with higher sulphur and zinc applications. The maximum number was recorded in the treatment S_3 (345.39) and Z_3 (340.11), compared to the control S_0 (271.80) and Z_0 (266.14).

4.2.2: The number of seeds per siliqua

Sulphur levels

The experimental results shown in Table 4.7 reveal that increasing the levels of sulphur enhanced this compared to the other treatments. The highest number of seeds per siliqua was observed with the application of the highest Sulphur level. The highest sulphur level was considerable when compared to both lower Sulphur levels and the control, showing a progressive improvement over the years and in the combined analysis. This improvement is likely the result of the overall positive impact of higher Sulphur levels on the plant's growth and yield characteristics. These findings align with the observations made by Singh and Kumar (2014).

Zinc application

Data (Table 4.7) specified that implication of zinc increasedper siliqua of gobhi sarson. Three spray of Zn increased by 28.08, 12.97 percent, 27.50, 12.77 and 27.79, 12.88 percent over control (Zn_0) and one treatment of zinc (Zn_1). This might be due to higher growth attributes in same treatments. Kaur et al. (2017) also found similar results which support present findings.

The critical scrutiny of the measured values is provided table 4.7. A gradual increase in the number of seeds per siliqua was observed with increased sulphur and zinc doses. The highest pooled values were 14.32 in S_3 and 13.86 in Z_3, whereas the controls S_0 and Z_0 recorded only 12.15 and 12.31, respectively.

4.2.3 Test weight (g)

Sulphur levels

Treatment sulphur @ 30 kg/ha (S_3) recorded significantly maximum test weight as compared to rest of the treatment. Sulphur @ 30 kg/ha (S_3) recorded 2.08, 4.93 and 24.37 percent higher test weight over S_2, S_1 and S_0 in pooled analysis. These consequences are in conformity with Parmar et al. (2010) who also obtained higher test weight, due to 45 kg S/ha application.

Zinc application

Data in table 4.7 signify that implication of zinc improved the test weight of gobhi sarson. The significant difference in test weight of gobhi sarson was obtained by three application of zinc (Zn_3) over control and Zn_1 which was found at par with two application of zinc (Zn_2). Three implication of zinc (Zn_3) increased the test weight of gobhi sarson by 41.70 and 12.30 percent over control and Zn_1 in pooled mean, respectively.

The 1000-seed weight improved with increasing levels of sulphur and zinc, indicating better seed development. The maximum test weight was recorded in S_3 (4.22 g) and Z_3 (4.20 g), notably higher than the control S_0 (3.89 g) and Z_0 (3.88 g).

Table 4.7: Effect of sulphur levels and zinc application on number of siliqua per plant, number of seeds per siliqua and Test weight of gobhi sarson

Treatments	Number of siliqua per plant			Number of seeds per siliqua			Test weight (g)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Sulphur levels									
S_0-Control	271.46	272.13	271.80	12.11	12.19	12.15	3.86	3.91	3.89
S_1-10 kg/ha	298.12	299.24	298.68	12.85	12.96	12.91	4.09	4.16	4.13
S_2-20 kg/ha	322.82	323.01	322.92	13.55	13.68	13.62	4.15	4.20	4.18
S_3-30 kg/ha	344.85	345.92	345.39	14.23	14.40	14.32	4.21	4.23	4.22
SEm±	6.46	6.58	4.61	0.23	0.24	0.17	0.07	0.08	0.06
CD (P=0.05)	18.65	19.00	13.04	0.68	0.71	0.48	0.22	0.24	0.16
Zinc application									
Z_0-Control	265.41	266.88	266.14	12.26	12.36	12.31	3.86	3.90	3.88
Z_1-1 appl.	300.91	301.72	301.31	12.99	13.12	13.05	4.12	4.17	4.14
Z_2-2 appl.	330.98	331.44	331.21	13.69	13.83	13.76	4.16	4.21	4.18
Z_3-3 appl.	339.95	340.26	340.11	13.80	13.92	13.86	4.18	4.23	4.20
SEm±	6.46	6.58	4.61	0.23	0.24	0.17	0.07	0.08	0.06
CD (P=0.05)	18.65	19.00	13.04	0.68	0.71	0.48	0.22	0.24	0.16
CV (%)	6.46	7.05	5.41	9.04	9.18	7.29	8.1	7.55	7.83
Interaction SxZn									
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

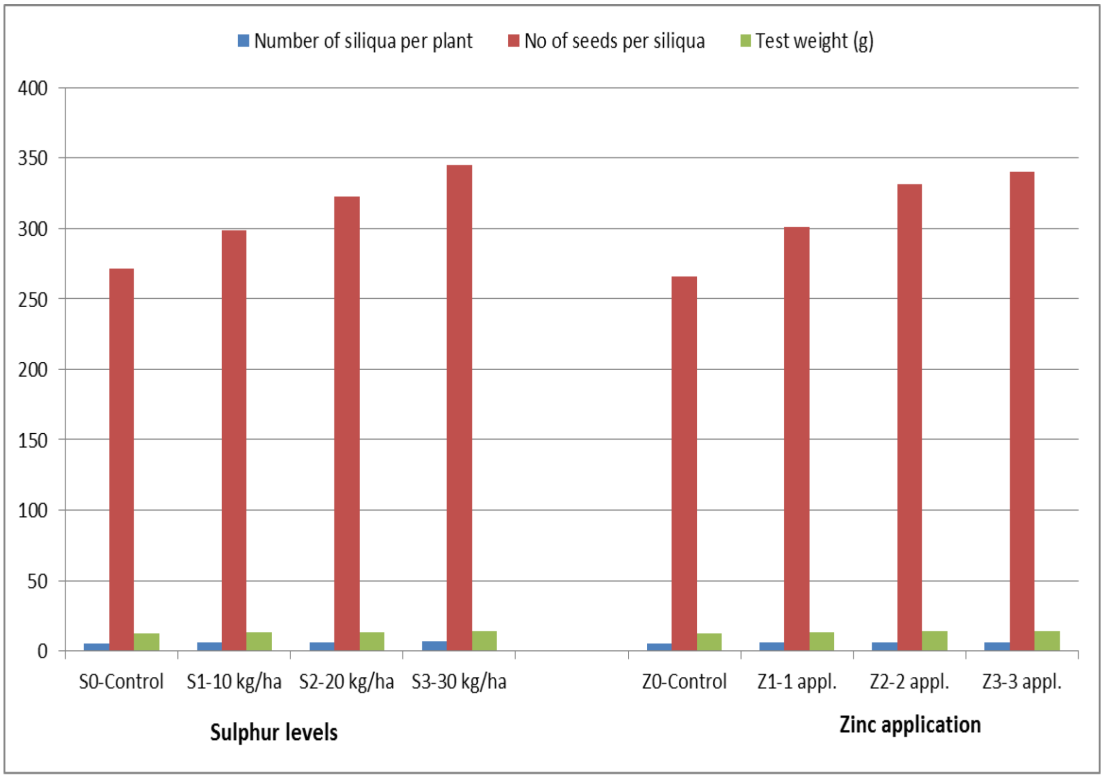


Fig. 4.2 Effect of sulphur levels and zinc application on number of siliqua per plant, number of seeds per siliqua

4.2.4: Seed yield (kg/ha)

Sulphur levels

The magnitude of seed yield due to use of sulphur @ 30 kg/ha in terms of percentage was 25.70, 13.22, 3.49; 25.55, 14.39, 4.60 and 25.59, 13.81, 5.09 over control (S0), sulphur @ 10 kg/ha (S_1) and sulphur @ 20 kg/ha (S_2) respectively. These results are conformity with (Singh and Kumar, 2014), (Ray et al. 2015) and (Parmar et al. 2010) who also obtained higher seed yield plant-1 due to 45 kg S/ha. Seed yield improved significantly with increasing sulphur doses, reaching a maximum pooled value of 2390 kg/ha with S_3.

Zinc application

Seed yield was observed with three foliar sprays, followed by two sprays, both of which were much higher compared to the control group and the one-spray treatment. The three-spray treatment resulted in notable increases in seed yield across multiple years and the overall average. These findings are consistent with the results of previous studies conducted by (Kaur et al. 2017), (Mishra et al. 2016), and (Nawaz et al. 2012), who also observed similar improvements in yield with zinc application. Zinc application enhanced seed yield, with the highest pooled value (2425 kg/ha) observed under Z_3.

Interaction

The data indicates that the interaction between sulphur levels and zinc application had a substantial effect on the seed yield. The combination of a specific Sulphur application with three zinc sprays resulted in the highest seed yield across multiple years, significantly outperforming the other treatment combinations.. In contrast, the lowest seed yield was observed when no Sulphur or zinc was applied, highlighting the positive impact of Sulphur and zinc on seed yield. The S × Zn interaction had a significant effect, indicating synergistic enhancement of seed yield when both nutrients were applied together.

4.2.5 Stover yield (kg/ha)

Sulphur levels

The data shows that the application of Sulphur at a specific level significantly improved the straw yield of Gobhi Sarson. The highest straw yield was achieved with a Sulphur application at 30 kg per hectare, which was notably higher than other treatments. The increase in straw yield can be attributed to various factors, including greater plant height, more branches, higher dry matter, and an increased number of siliqua per plant. These results are consistent with findings from other studies, further supporting the beneficial effects of Sulphur on plant growth and yield. Stover yield showed a consistent increase with higher sulphur levels, peaking at 6065 kg/ha under S_3.

Zinc application

The data demonstrates that applying zinc notably boosted the straw yield of Gobhi Sarson in comparison to the control group and the initial zinc application. The highest straw yield was achieved with three application of zinc, which significantly outperformed both the control and the first zinc application. The increase in straw yield with three zinc application was considerable, with the largest percentage gain observed compared to the control. Maximum pooled stover yield (5873 kg/ha) was recorded under Z_3, confirming the positive role of zinc in biomass production.

Interaction

The data presented in Table 4.10 illustrates the interaction effect of Sulphur levels and zinc application on the straw yield of Gobhi Sarson. The combination of 30 kg/ha of Sulphur with three application of zinc (S_3Zn_3) resulted in the highest straw yield, significantly surpassing all other treatment combinations.. The lowest straw yield was observed in the control group (S_0Zn_0), with markedly lower values compared to the other treatments during the years 2022-23, 2023-24, and the pooled analysis. A significant S × Zn interaction was observed, suggesting that combined nutrient application effectively boosted stover yield.

4.2.6: Biological yield (kg/ha)

Sulphur sources

The data shows that using a specific type of Sulphur significantly boosted the biological yield of mustard plants. Among the different suphur sources tested, the one used in higher amounts gave the best results, producing more yields compared to the others. The increase in yield was noticeable when compared to the other two Sulphur sources, with a higher percentage of improvement seen in both years of the study and when the results from both years were combined. Biological yield increased from 6483 kg/ha in control to 8455 kg/ha in S_3, showing a direct positive response to sulphur application.

Zinc application

A close perusal of data related to biological yield of gobhi sarson by increasing levels of zinc is existing in table 4.8. The results showed that zinc treatment greatly increased the biological yield of gobhi sarson when compared to control and Zn_1. Three zinc (Zn_3) treatments resulted in the maximum straw yield (8254, 8341, and 8297 kg/ha) of gobhi sarson, which was substantially greater than the control (6324, 6387, and 6355 kg/ha). Three zinc (Zn_3) application were 30.16, 13.51; 30.16, 14.06; and 26.23, 13.10 percent above control and Zn1, for every year and in averaged mean, respectively. Zinc supplementation elevated biological yield, with Z_3 producing the highest pooled yield of 8297 kg/ha.

Interaction

The data shows that the combination of Sulphur and zinc had a significant impact on the biological yield of mustard. Specifically, when Sulphur was applied at a certain level and zinc was applied three times, the yield was much higher compared to other treatment combinations.. This effect was consistent across both years of the study and in the overall results. Significant interaction between sulphur and zinc indicated enhanced total productivity through integrated nutrient management. The siliqua formation is also directly related to the conductive condition for the formation of more siliqua such as increase in CO_2 assimilation rate, delay in senescence of flag leaf and effective translocation of dry matter from source to sink which together resulted in production of higher number of siliqua with longer siliqua length (Cocucci and Dallarosa, 1998). Use of hydrogel made available soil moisture to optimum level during growth period, which helped in better leaf area expansion and photosynthesis, ultimately greater plant growth and development, reflected from higher values of yield attributes.

This increment in crop productivity with application of hydrogel might be a result of higher plant growth, dry matter accumulation and yield attributes due to optimum availability of water compared to other treatments. Our findings align closely with those reported by previous studies (Akhter et al. 2004 and Rehman et al. 2011) who stated that application of hydrogels resulted in higher crop productivity. An increase in yield and yield related attributes could be because of sufficient availability of water and indirectly nutrients supplied by the SAP to the plants under water stress condition, which in turn lead to better translocation of water, nutrients and photosynthates and finally better plant stand and yield (El Hardy et al., 2009). It may be attributed with super absorbing properties of the hydrogel which absorbs the water and releases it slowly to the growing plants as per the crop needs.

4.2.7: Harvest Index (%)

Sulphur levels

A higher harvest index signifies a greater proportion of biomass allocated to the economically useful part, thereby reflecting better crop productivity and resource use efficiency. In other words, despite increasing the Sulphur levels, the soil's acidity or alkalinity remained unchanged by the end of the growing season. Harvest index slightly decreased with increasing sulphur levels, showing a pooled value of 28.23% in S_3 compared to 29.34% in S_0.

Zinc application

Zinc application slightly improved the harvest index, with the highest pooled value of 29.25% in Z_3. No significant interaction effect was noted for harvest index, suggesting that individual nutrient effects predominated.However, while sulphur and zinc application may increase overall biomass and seed yield, their effect on HI may not always be proportionally significant. Therefore, understanding HI in response to nutrient treatments helps in optimizing fertilizer strategies for improved yield quality and resource utilization.

Table 4.8: Effect of sulphur levels and zinc application on seed, stover and Biological yield and Harvest index of gobhi sarson

Treatments	Seed yield (kg/ha)			Stover yield (kg/ha)			Biological yield (kg/ha)			Harvest index (%)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Sulphur levels												
S_0-Control	1887	1918	1903	4574	4586	4580	6461	6504	6483	29.21	29.47	29.34
S_1-10 kg/ha	2095	2105	2100	5087	5128	5107	7182	7233	7207	29.13	29.07	29.10
S_2-20 kg/ha	2292	2302	2297	5584	5659	5621	7876	7960	7918	29.03	28.84	28.94
S_3-30 kg/ha	2372	2408	2390	6048	6082	6065	8420	8490	8455	28.11	28.36	28.23
SEm±	35.15	32.54	23.95	68.97	70.93	49.47	105.48	97.46	71.81	0.55	0.62	0.42
CD (P=0.05)	101.53	94.00	67.76	199.20	204.87	139.94	304.66	281.47	203.13	NS	NS	NS
Zinc application												
Z_0-Control	1784	1815	1800	4540	4572	4556	6324	6387	6355	28.23	28.42	28.32
Z_1-1 appl.	2100	2113	2106	5196	5223	5209	7296	7336	7316	28.89	28.91	28.90
Z_2-2 appl.	2349	2368	2358	5716	5756	5736	8065	8124	8094	29.11	29.16	29.13
Z_3-3 appl.	2413	2436	2425	5841	5905	5873	8254	8341	8297	29.25	29.25	29.25
SEm±	35	33	24	69	71	49	105	97	72	0.55	0.62	0.42
CD (P=0.05)	102	94	68	199	205	140	305	281	203	NS	NS	NS
CV (%)	7.04	6.46	5.40	5.61	5.73	4.54	6.10	5.59	4.68	8.29	9.29	7.04
Interaction SxZn												
CD (P=0.05)	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	N.Sig.	N.Sig.	N.Sig.

Table 4.9: Interactiveeffects of sulphur levels and zinc application on seed yield of gobhi sarson

Treatments	**2022-23**			
	S_0	S_1	S_2	S_3
Z_0	1654	1738	1863	1881
Z_1	1947	2052	2191	2210
Z_2	1965	2217	2567	2645
Z_3	1983	2373	2546	2751
SEm$\pm$	**70.31**			
CD (P=0.05)	**203.06**			
2023-24				
	S_0	S_1	S_2	S_3
Z_0	1658	1743	1868	1991
Z_1	1954	2061	2200	2237
Z_2	2008	2232	2582	2649
Z_3	2052	2384	2556	2753
SEm$\pm$	**65**			
CD (P=0.05)	**188**			
		Pooled		
	S_0	S_1	S_2	S_3
Z_0	1656	1741	1866	1936
Z_1	1951	2056	2195	2224
Z_2	1987	2225	2575	2647
Z_3	2018	2379	2551	2752
SEm$\pm$	**48**			
CD (P=0.05)	**136**			

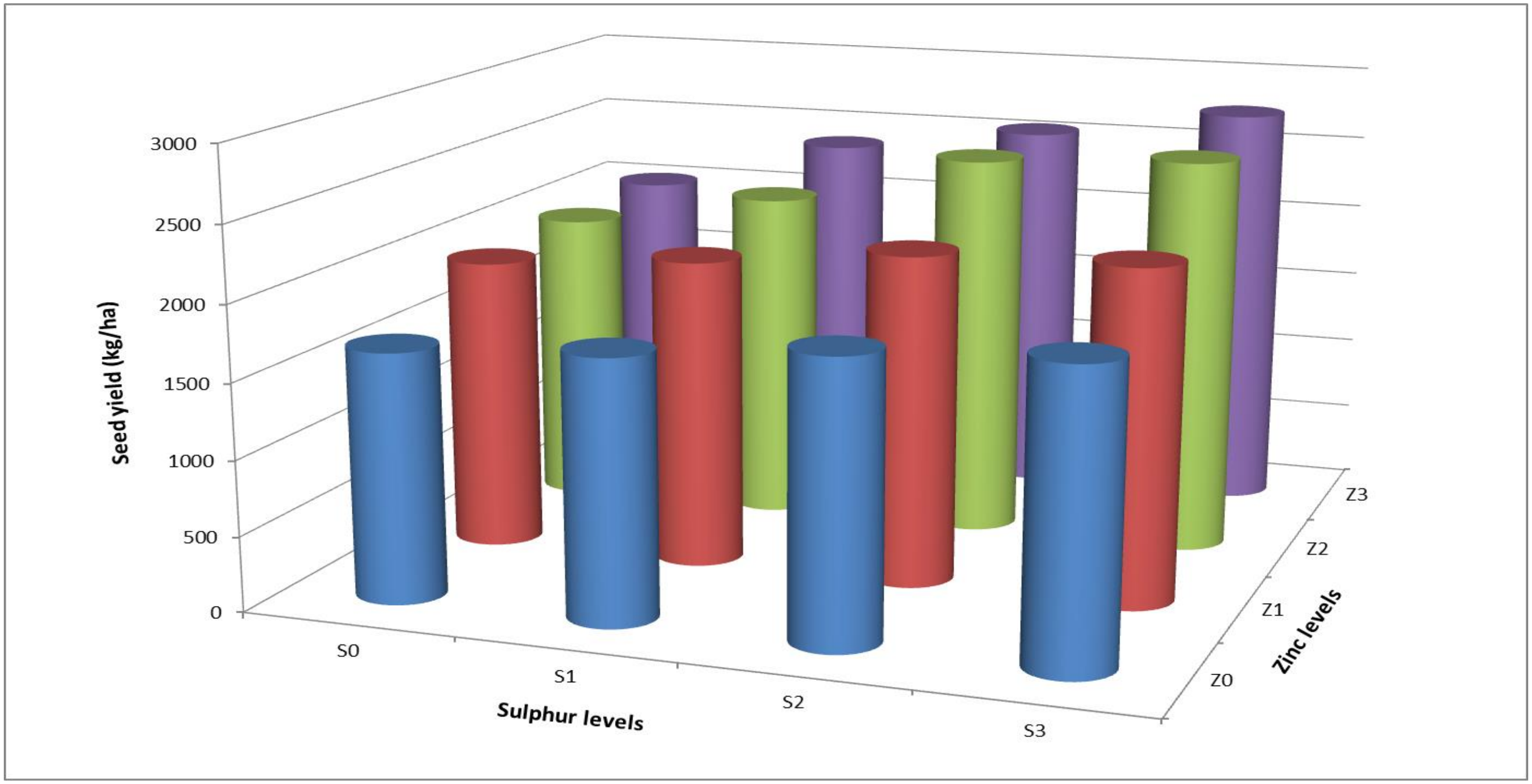


Fig.4.3: Effect of sulphur levels and zinc application on seed yield of gobhi sarson.

Table 4.10: Interactive effects of sulphur levels and zinc application on stover yield of gobhi sarson

Treatments	**2022-23**			
	S_0	S_1	S_2	S_3
Z_0	4154	4345	4769	4892
Z_1	4419	4982	5468	5914
Z_2	4841	5457	5989	6577
Z_3	4881	5563	6109	6809
SEm$\pm$	**138**			
CD (P=0.05)	**398**			
2023-24				
	S_0	S_1	S_2	S_3
Z_0	4167	4378	4831	4910
Z_1	4424	5009	5527	5932
Z_2	4853	5494	6062	6616
Z_3	4901	5630	6215	6872
SEm$\pm$	**142**			
CD (P=0.05)	**410**			
Pooled				
	S_0	S_1	S_2	S_3
Z_0	4161	4362	4800	4901
Z_1	4422	4995	5498	5923
Z_2	4847	5475	6026	6597
Z_3	4891	5597	6162	6841
SEm$\pm$	**99**			
CD (P=0.05)	**280**			

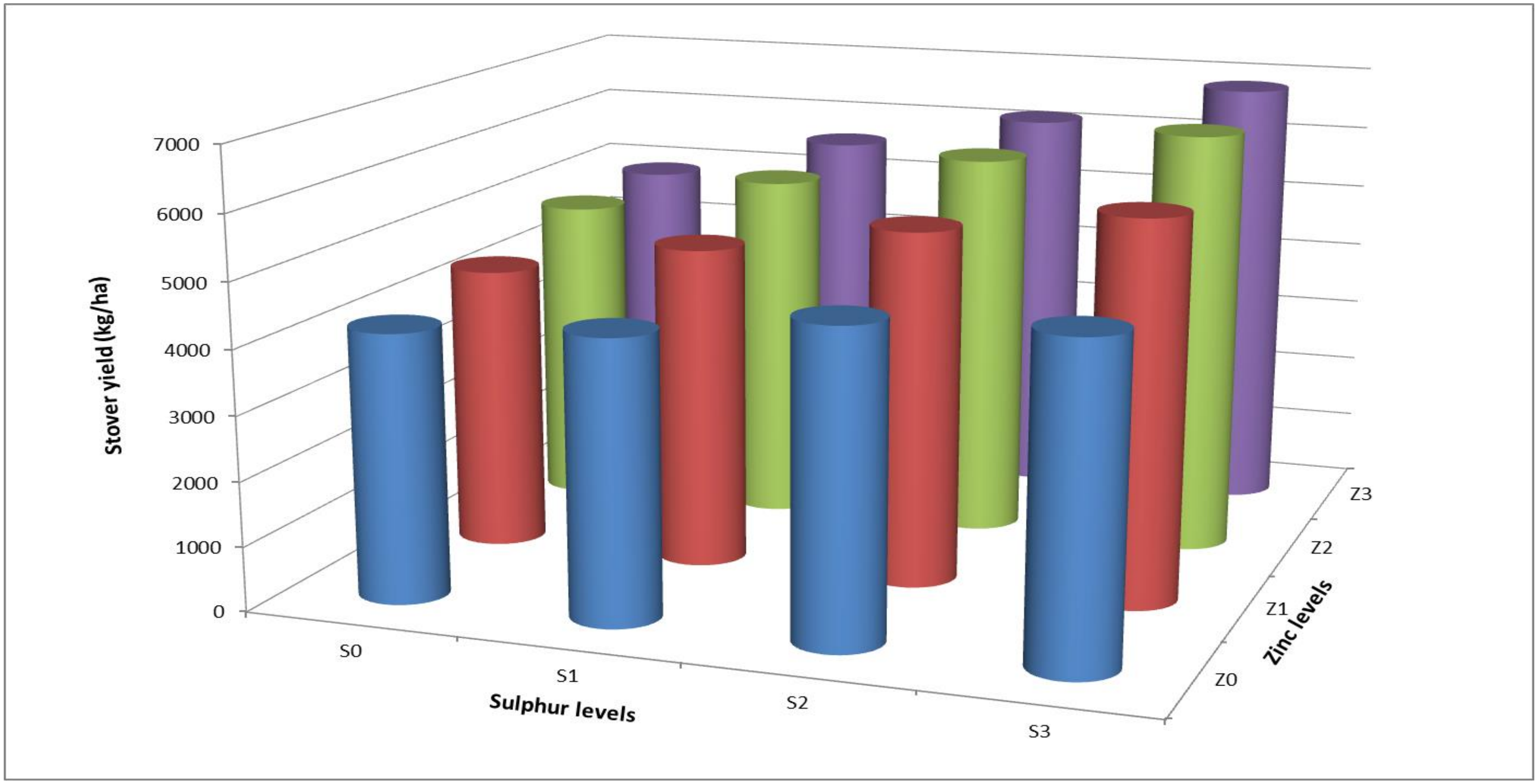


Fig.4.1: Effect of sulphur levels and zinc application on stover of gobhi sarson.

Table 4.11: Interactive effects of sulphur levels and zinc application on Biological yield of gobhi sarson

Treatments	2022-23			
	S_0	S_1	S_2	S_3
Z_0	5808	6083	6632	6773
Z_1	6367	7033	7659	8124
Z_2	6806	7674	8556	9222
Z_3	6864	7936	8655	9560
SEm±	**211**			
CD (P=0.05)	**609**			
2023-24				
	S_0	S_1	S_2	S_3
Z_0	5825	6121	6699	6901
Z_1	6378	7070	7727	8169
Z_2	6861	7726	8645	9265
Z_3	6953	8014	8771	9625
SEm±	**195**			
CD (P=0.05)	**563**			
		Pooled		
	S_0	S_1	S_2	S_3
Z_0	5817	6102	6666	6837
Z_1	6372	7052	7693	8147
Z_2	6833	7700	8601	9244
Z_3	6909	7975	8713	9593
SEm±	**144**			
CD (P=0.05)	**406**			

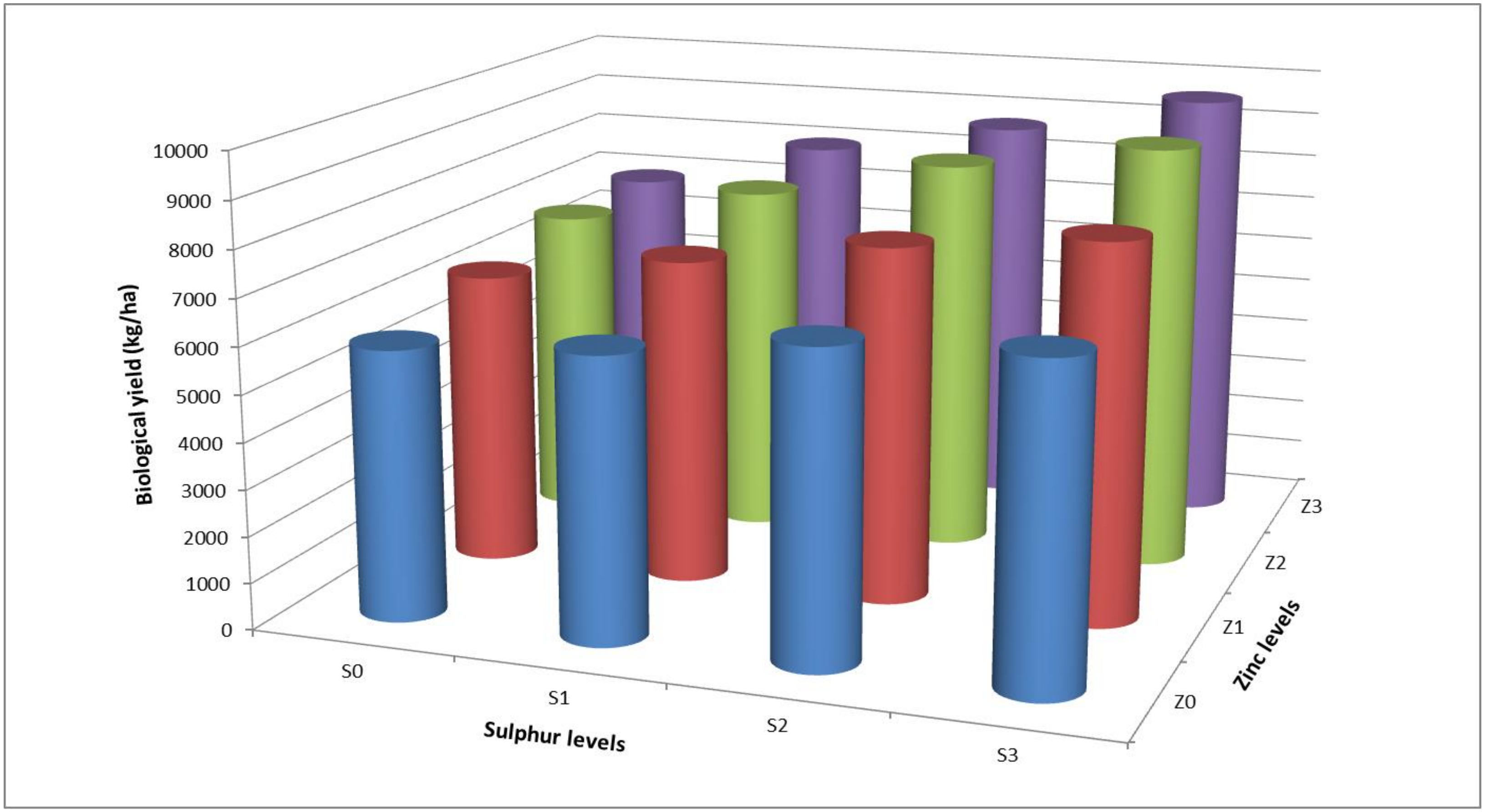


Fig.4.5: Interactive effect of zinc application and sulphur levels on biological yield of gobhi sarson.

4.2.8: Protein content (%)

Sulphur levels

A detailed analysis of the data presented in Table 4.12 revealed that increasing sulphur levels had a significant and positive influence on the protein content of gobhi sarson seeds. The pooled data showed that the highest protein content (20.71%) was observed with sulphur application at 30 kg/ha (S_3), followed by 20.42% at 20 kg/ha (S_2) and 19.62% at 10 kg/ha (S_1). In contrast, the lowest value (18.38%) was recorded under the control (S_0). These results confirm that the progressive increase in sulphur supply significantly enhanced protein accumulation in seeds, likely due to improved nitrogen and sulphur assimilation and their synergistic role in amino acid and protein synthesis. This trend corroborates the earlier findings of Kumar and Trivedi (2012), who also reported an increase in protein content with higher fertilizer inputs.

Zinc application

Protein content in seeds of gobhi sarson also varied significantly with zinc application. The maximum pooled protein content (20.73%) was recorded under three zinc applications (Zn_3), which was statistically at par with two applications (Zn_2) at 20.40%, and both were significantly superior to Zn_1 (19.62%) and the control (Zn_0) (18.37%). These observations indicate that zinc plays a vital role in enhancing protein synthesis by influencing enzymatic activity and metabolic processes. The results are in agreement with those reported by Sonune et al. (2001), Singh and Singh (2005), and Nadaf et al. (2013), who highlighted the significant improvement in quality attributes of oilseed crops following zinc fertilization.

4.2.9: Oil content (%)

Sulphur levels

The analysis of the pooled data indicates that increasing sulphur levels had a favourable effect on the oil content of gobhi sarson seeds. The maximum oil content (40.25%) was recorded under the highest sulphur level of 30 kg/ha (S_3), followed closely by 40.09% in the 20 kg/ha (S_2) treatment. These values were markedly higher than the control (36.21%) and the 10 kg/ha treatment (38.18%). This trend demonstrates that elevated sulphur availability enhances oil biosynthesis in seeds, likely due to its role in enzymatic activation and fatty acid formation pathways. The comparable effects of medium and high sulphur levels suggest a saturation point beyond which oil accumulation stabilizes.

Zinc application

Zinc application also influenced the oil content positively. The pooled data show that three zinc applications (Zn_3) resulted in the highest oil content (38.85%), which was statistically at par with Zn_2 (38.80%), and both were significantly superior to Zn_1 (38.68%) and the control (Zn_0) (38.40%). The improvement in oil content due to Zn_3 over the control corresponds to a 4.07% increase, confirming the positive influence of repeated zinc applications. These results are in alignment with the findings of Deo and Khandelwal (2009), who also reported enhanced oil content with zinc supplementation in oilseed crops.

A critical examination of Table 4.12 reveals that the interaction between sulphur levels and zinc application did not exert a statistically significant influence on oil content, suggesting that their individual effects predominated in determining this quality trait.

4.2.10: Oil yield (kg/ha)

Sulphur levels

A detailed examination of the data in Table 4.12 indicates that varying sulphur levels significantly influenced the oil yield of gobhi sarson. The highest oil yield was recorded under the application of sulphur at 30 kg/ha (S_3), with a pooled mean value of 962.32 kg/ha. This was notably higher than that under S_2 (921.25 kg/ha), S_1 (802.17 kg/ha), and the control (S_0), which recorded the lowest value of 689.18 kg/ha. The increase in oil yield under S3, when compared to S_0, S_1, and S_2, was 40.03%, 20.13%, and 4.47%, respectively. These findings clearly demonstrate the beneficial role of sulphur in enhancing oil accumulation and seed productivity. Similar results were reported by Sharma and ISSA (2006) and Singh and Mukherjee (2004), who also observed increased oil yield in response to higher sulphur application.

Zinc application

The data further indicated that zinc application had a significant impact on oil yield. The maximum oil yield was achieved with three zinc applications (Zn_3), which recorded 946.36 kg/ha, followed by Zn_2 (919.32 kg/ha). Both were significantly superior to Zn_1 (816.53 kg/ha) and the control (Zn_0) (692.71 kg/ha). The oil yield increase under Zn_3, compared to

Zn_0 and Zn_1, was 40.03% and 20.13%, respectively, in pooled analysis. The corresponding increases for 2022–23 were 13.90% (Zn_3 vs. Zn_0) and 19.36% (Zn_3 vs. Zn_1), and for 2023–24 were 40.16% and 20.90%, respectively. These results are in accordance with the findings of Deo and Khandelwal (2009) and Nadaf et al. (2013), who also reported significant enhancement in oil yield with increasing levels of zinc.

Interaction (Sulphur × Zinc)

Unlike oil content, the interaction between sulphur levels and zinc application was found to be statistically significant for oil yield across both years and in pooled data. The highest oil yield was obtained from the combined treatment of sulphur at 30 kg/ha with three applications of zinc (S_3Zn_3), reflecting a considerable improvement over all other combinations. Conversely, the lowest oil yield was recorded under the control (S_0Zn_0), where no sulphur or zinc was applied. This interaction highlights the synergistic effect of sulphur and zinc in enhancing oil productivity in gobhi sarson.

.

Table 4.12: Effect of sulphur levels and zinc application on protein, oil content and oil yield of gobhi sarson

Treatments	**Protein content (%)**			**Oil content (%)**			**Oil yield (kg/ha)**		
Sulphur levels	**2022-23**	**2023-24**	**Pooled**	**2022-23**	**2023-24**	**Pooled**	**2022-23**	**2023-24**	**Pooled**
S_0-Control	18.34	18.41	18.38	36.16	36.26	36.21	682.70	695.66	689.18
S_1-10 kg/ha	19.59	19.64	19.62	38.12	38.24	38.18	799.01	805.33	802.17
S_2-20 kg/ha	20.41	20.43	20.42	39.97	40.21	40.09	916.53	925.98	921.25
S_3-30 kg/ha	20.69	20.73	20.71	40.13	40.36	40.25	952.40	972.24	962.32
SEm$\pm$	0.22	0.23	0.16	0.64	0.68	0.47	15.93	13.02	10.29
CD (P=0.05)	0.63	0.66	0.44	1.84	1.96	1.32	46.01	37.61	29.10
Zinc application									
Z_0-Control	18.36	18.38	18.37	38.31	38.49	38.40	684.95	700.47	692.71
Z_1-1 appl.	19.59	19.64	19.62	38.59	38.77	38.68	812.13	820.94	816.53
Z_2-2 appl.	20.38	20.42	20.40	38.71	38.89	38.80	913.43	925.20	919.32
Z_3-3 appl.	20.70	20.76	20.73	38.77	38.93	38.85	940.13	952.60	946.36
SEm$\pm$	0.00	0.23	0.16	0.64	0.68	0.47	15.93	13.02	10.29
CD (P=0.05)	0.00	0.66	0.44	1.84	1.96	1.32	46.01	37.61	29.10
CV (%)	4.75	4.98	3.89	7.15	7.59	5.90	8.24	6.64	5.97
Interaction SxZn									
CD (P=0.05)	NS	NS	NS	NS	NS	NS	Sig.	Sig.	Sig.

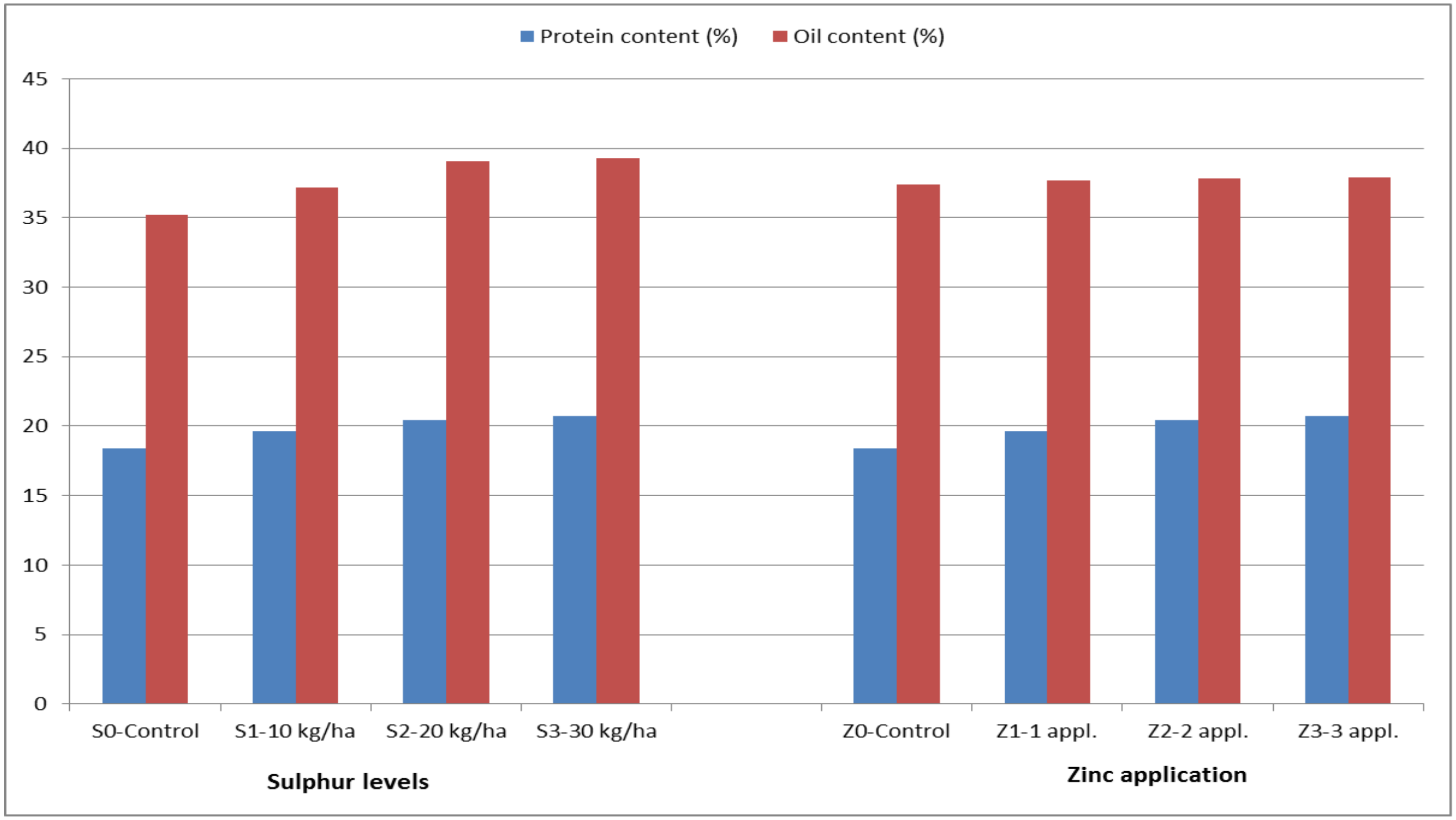


Fig.4.6: Effect of sulphur levels and zinc application on protein content and oil content in seed of gobhi sarson

Table 4.13: Interactive effect of sulphur levels and zinc application on oil yield of gobhi sarson

Treatments	**2022-23**			
	S_0	S_1	S_2	S_3
Z_0	576.92	640.02	720.24	730.19
Z_1	684.64	761.47	853.73	864.66
Z_2	693.09	825.58	1003.46	1038.20
Z_3	700.70	885.25	997.12	1081.83
SEm±	**31.86**			
CD (P=0.05)	**92.02**			
2023-24				
	S_0	S_1	S_2	S_3
Z_0	580.01	643.99	726.68	777.49
Z_1	688.77	767.35	862.52	880.59
Z_2	710.40	834.06	1016.03	1046.22
Z_3	726.79	891.80	1006.72	1088.46
SEm±	**26.04**			
CD (P=0.05)	**75.22**			
		Pooled		
	S_0	S_1	S_2	S_3
Z_0	578.47	642.00	723.46	753.84
Z_1	686.71	764.41	858.12	872.62
Z_2	701.74	829.82	1009.75	1042.21
Z_3	713.75	888.52	1001.92	1085.15
SEm±	**20.58**			
CD (P=0.05)	**58.20**			

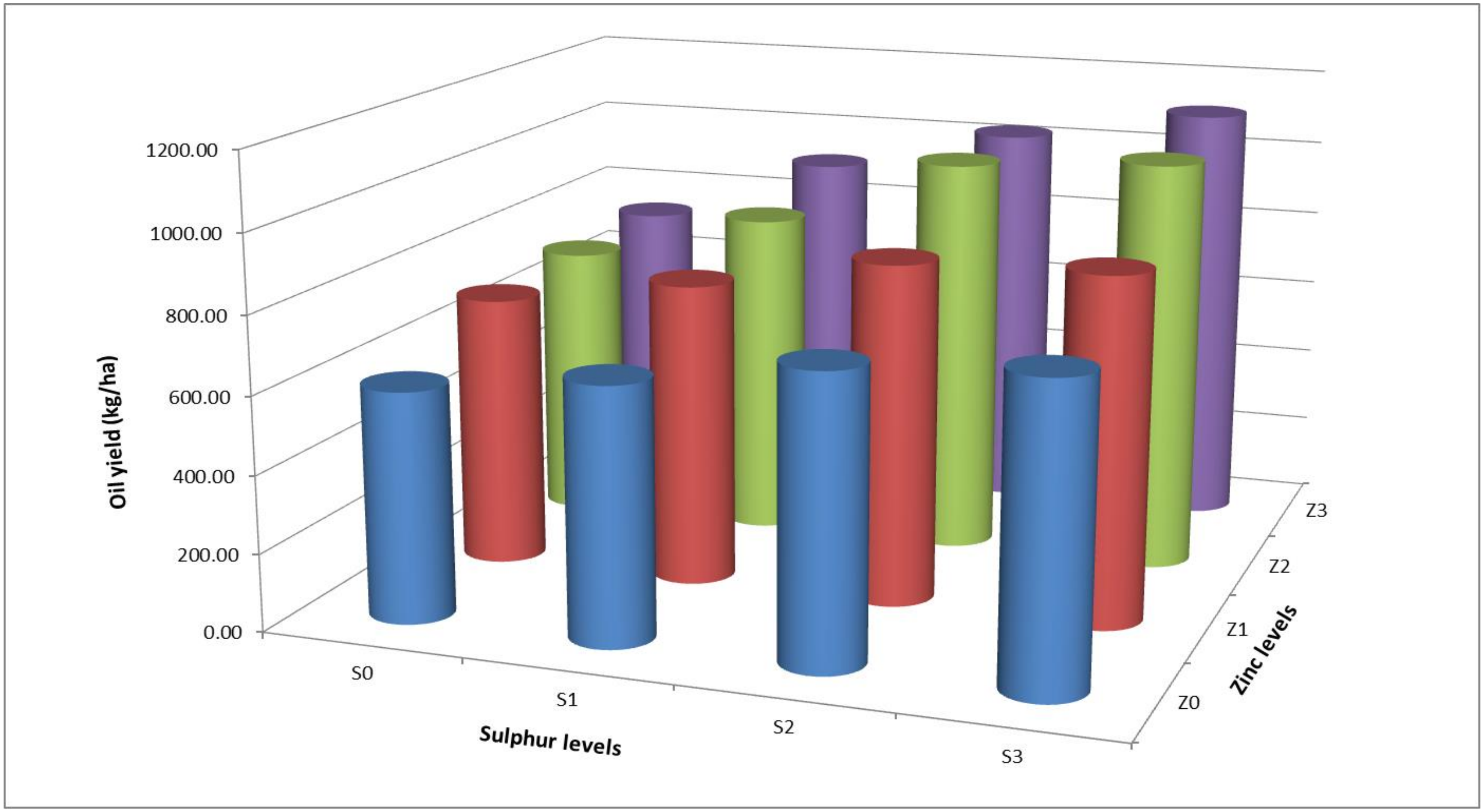


Fig 4.7: Interactive effect of zinc application and sulphur levels on oil yield of gobhi sarson.

4.3 Soil studies

4.3.1 pH

Sulphur levels

A comprehensive analysis of the data presented in Table 4.14 indicates that varying sulphur levels did not exert a statistically significant influence on soil pH at harvest. The pooled pH values remained nearly constant across treatments, ranging from 7.83 in the control (S_0) to 7.80 under higher sulphur applications (S_2 and S_3). These differences, although numerically minor, were not statistically significant, indicating that sulphur application up to 30 kg/ha did not lead to notable acidification of the soil.

Zinc application

Similarly, different levels of zinc application did not produce any significant effect on soil pH at harvest. The pooled pH values varied narrowly, from 7.83 in the control (Zn_0) to 7.80–7.81 in the treated plots (Zn_1 to Zn_3). These results confirm the buffering capacity of the soil and indicate that zinc application had a negligible effect on altering soil pH over the two-year study period.

4.3.2 EC

Sulphur levels

As shown in Table 4.14, sulphur application levels did not significantly affect the electrical conductivity (EC) of the soil at harvest. Pooled EC values remained constant at 0.41 dS/m across all treated plots (S_1 to S_3), while the control (S_0) recorded a slightly higher but statistically insignificant value of 0.42 dS/m.

Zinc application

Similar to sulphur, the application of zinc did not cause any significant variation in soil EC. All treatments, including control and varying zinc application frequencies, recorded pooled EC values in the range of 0.41–0.42 dS/m, with Zn_0 slightly higher at 0.42 dS/m. Thus, neither sulphur nor zinc application adversely affected the salinity status of the soil.

4.3.3 CEC

Sulphur levels

An analysis of the data in Table 4.14 showed that the cation exchange capacity (CEC) of the soil remained unaffected by different levels of sulphur application. The pooled CEC values ranged from a maximum of 30.82 cmol/kg in the control (S_0) to a minimum of 30.18 cmol/kg under the highest sulphur dose (S_3). However, these differences were not statistically significant.

Zinc application

The pooled data revealed that the highest CEC value (30.81 cmol/kg) was recorded under three applications of zinc (Zn_3), followed closely by Zn_2 (30.75 cmol/kg) and Zn_1 (30.71 cmol/kg). The lowest CEC was noted in the control (Zn_0) with 30.17 cmol/kg. Although these values suggest a trend of increasing CEC with higher zinc application, the differences were statistically non-significant. Therefore, zinc application had a limited but potentially beneficial role in maintaining or slightly enhancing soil CEC.

4.3.4: Available Nitrogen (N)

Sulphur levels

According to the data in Table 4.15, the increasing levels of sulphur had no statistically significant effect on the available nitrogen content in the soil after harvest. The pooled nitrogen content ranged narrowly from 192.03 kg/ha in the control (S_0) to 197.30 kg/ha under the highest sulphur application (S_3), but these differences were not significant.

Zinc application

Similar to sulphur, zinc application did not lead to significant changes in soil nitrogen levels. The pooled available nitrogen content ranged from 191.73 kg/ha (Zn_0) to 197.24 kg/ha (Zn_3), indicating a minor numerical increase, but statistically non-significant.

4.3.5: Available Phosphorus (P_2O_5)

Sulphur levels

An analysis of Table 4.15 indicates that increasing sulphur levels did not significantly affect the availability of phosphorus in the soil. The pooled phosphorus content ranged from 30.19 kg/ha under control (S_0) to 31.12 kg/ha in S_3, but this variation remained within non-significant limits.

Zinc application

The impact of zinc application on available phosphorus was similarly negligible. The pooled phosphorus content ranged from 30.54 kg/ha (Zn_2) to 31.03 kg/ha (Zn_0), again showing no statistically significant difference between treatments.

4.3.6: Available Potassium (K_2O)

Sulphur levels

The potassium availability in the soil after harvest showed no significant differences among sulphur treatments. Pooled values ranged from 202.12 kg/ha in S0 to 209.79 kg/ha in S_3, but these increases were statistically non-significant.

Zinc application

Zinc application exhibited a similar trend. The available potassium content ranged from 202.15 kg/ha (Zn_0) to 209.68 kg/ha (Zn_3). Despite the incremental rise with increasing zinc application, the variations were statistically insignificant across the years.

4.3.7: Available Zinc (Zn)

Sulphur levels

An evaluation of the data revealed that sulphur application levels did not significantly affect the zinc content in soil. The pooled zinc availability ranged from 0.434 kg/ha in the control (S_0) to 0.448 kg/ha in the S_3 treatment.

Zinc application

Zinc application had a minor but progressive effect on available soil zinc. The pooled zinc content increased from 0.433 kg/ha (Zn_0) to 0.447 kg/ha (Zn_3). However, these differences remained statistically non-significant.

4.3.8: Available Sulphur (S)

Sulphur levels

Unlike other nutrients, the available sulphur content in the soil increased steadily with rising sulphur application. The pooled sulphur content ranged from 7.54 kg/ha under control (S_0) to a maximum of 8.03 kg/ha in the 30 kg/ha treatment (S_3). Although the increase was small, it indicates a consistent trend of residual sulphur accumulation with higher sulphur doses. However, this trend was statistically non-significant as per the CD values.

Zinc application

Available sulphur content also showed minor variation due to zinc application. The pooled values increased from 7.61 kg/ha (Zn_0) to 7.95 kg/ha (Zn_3), but like sulphur treatments, the differences among zinc levels were not statistically significant.

Table 4.14: Effect of sulphur levels and zinc application on pH, EC and CEC at harvest of gobhi sarson

Treatments	**pH**			**EC (dS/M)**			**CEC**		
	2022-23	**2023-24**	**Pooled**	**2022-23**	**2023-24**	**Pooled**	**2022-23**	**2023-24**	**Pooled**
Sulphur levels									
S_0-Control	7.83	7.83	7.83	0.42	0.42	0.42	30.81	30.82	30.82
S_1-10 kg/ha	7.81	7.81	7.81	0.41	0.41	0.41	30.75	30.77	30.76
S_2-20 kg/ha	7.80	7.80	7.80	0.41	0.41	0.41	30.68	30.70	30.69
S_3-30 kg/ha	7.80	7.80	7.80	0.41	0.41	0.41	30.16	30.19	30.18
SEm$\pm$	0.16	0.17	0.12	0.04	0.05	0.03	0.64	0.71	0.48
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Zinc application									
Z_0-Control	7.83	7.83	7.83	0.42	0.42	0.42	30.16	30.18	30.17
Z_1-1 appl.	7.81	7.81	7.81	0.41	0.41	0.41	30.69	30.73	30.71
Z_2-2 appl.	7.80	7.81	7.80	041	0.41	0.41	30.75	30.75	30.75
Z_3-3 appl.	7.81	7.82	7.81	0.41	0.41	0.41	30.81	30.82	30.81
SEm$\pm$	0.16	0.17	0.12	0.04	0.05	0.03	0.64	0.71	0.48
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	8.66	9.52	7.28	9.04	9.89	7.58	9.06	10.01	7.64
Interacton S xZn									
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4.15: Effect of sulphur levels and zinc application on available N, P, K, Zn and S content in soil after harvest of gobhi sarson

Treatments	Available N (kg/ha)			Available P_2O_5 (kg/ha)			Available K_2O (kg/ha)			Available Zn (kg/ha)			Available S (kg/ha)		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Sulphur levels															
S_0-Control	191.95	192.10	192.03	30.16	30.21	30.19	201.93	202.31	202.12	0.433	0.435	0.434	7.52	7.55	7.54
S_1-10 kg/ha	194.25	194.61	194.43	30.65	30.71	30.68	206.12	207.65	206.89	0.438	0.440	0.439	7.75	7.81	7.78
S_2-20 kg/ha	195.82	196.00	195.91	30.91	30.96	30.94	208.91	209.63	209.27	0.442	0.445	0.444	7.89	7.96	7.93
S_3-30 kg/ha	197.22	197.38	197.30	31.09	31.15	31.12	209.46	210.11	209.79	0.446	0.449	0.448	8.01	8.05	8.03
SEm±	4.66	4.76	3.33	0.56	0.61	0.41	4.19	4.57	3.10	0.005	0.006	0.004	0.15	0.13	0.10
CD (P=0.05)	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig
Zinc application															
Z_0-Control	191.62	191.83	191.73	31.14	30.92	31.03	201.82	202.48	202.15	0.432	0.434	0.433	7.59	7.63	7.61
Z_1-1 appl.	194.41	194.71	194.56	30.89	30.70	30.79	206.34	207.52	206.93	0.438	0.440	0.439	7.78	7.83	7.81
Z_2-2 appl.	196.12	196.16	196.14	30.63	30.45	30.54	208.92	209.69	209.31	0.443	0.447	0.445	7.88	7.92	7.90
Z_3-3 appl.	197.09	197.38	197.24	30.15	30.96	30.56	209.34	210.01	209.68	0.446	0.448	0.447	7.91	7.99	7.95
SEm±	4.66	4.76	3.33	0.56	0.61	0.41	4.19	4.57	3.10	0.005	0.006	0.004	0.15	0.13	0.10
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	10.35	10.58	8.37	7.85	8.57	6.57	8.78	9.53	7.33	4.98	6.28	4.54	8.09	7.21	6.13
Interaction .xZn															
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.4: Nutrient content, uptake and quality parameters

4.4.1: Nitrogen content (%)

Sulphur levels

The data in Table 4.15, the nitrogen content of gobhi sarson seed and straw was greatly affected by rising sulphur levels. In 2022–2023 and 2023–2024, the Sulphur @ 30 kg/ha (S_3) recorded a considerably greater nitrogen content in seed and straw, and in combined analysis, it outperformed the control. The current findings are supported by (Kumar and Trivedi, 2012) observation that increased fertilizer doses resulted in higher protein content.

Zinc application

A critical examination of data revealed that nitrogen content in seed and straw of gobhi sarson was significantly varied due to implication of zinc in both years and the averaged mean. The higher nitrogen in both seed as well as straw was recorded under the treatment three implications.of zinc (Zn_3) over rest of the treatments which were remained at par with Zn_2. Sonune et al. (2001), Singh and singh (2005) and Nadaf et al. (2013). There results support the present findings.

4.4.2 Nitrogen uptake (kg/ha)

Sulphur levels

An analysis of the data shown in Table 4.16 suggested that increase in the nitrogen uptake by seed and straw of gobhi sarson. Pooled basis, the treatment sulphur *i.e.*, S_3 (30 kg S/ha) recorded the maximum nitrogen uptake by seed and straw under the treatment S_3 (80.83 and 39.64 kg/ha) over the control treatment. The percent increase recorded in S_3 over the control S_0 was 52.42, 21.96 percent and over S_1 was 45.36, 19.04 percent, respectively. The treatment S_3 was followed by the treatment S_2-20 kg S/ha (77.38 and 38.44 kg/ha), respectively.

Zinc application

The experimental findings presented in table (4.16) stated that the implication of zinc amplified the nitrogen uptake by both seed as well as straw of gobhi sarson as compared to control. Usage of zinc Zn_3 (three application) was recorded significantly maximum nitrogen uptake by seed and straw of gobhi sarson as compared to rest of the treatments. Nitrogen uptake by seed and straw increased due to zinc application of Zn_3 (Three application) to the tune of 52.42, 21.97 and 4.46 percent and 45.36, 19.04 and 3.12 % in seed and straw over control (Zn_0), one application of zinc (Zn_1) and two application of zinc (Zn_2), respectively.

Interaction

An analysis of the data shown in Table 4.17, 4.18 suggestedthat the interaction effect of sulphur levels with application of Zn on nitrogen uptake of gobhi sarson has been found to be small in both years and the averaged mean. The treatment combination, sulphur @ 30 kg/ha with three application of zinc (S_3Zn_3) (95.39, 95.71 and 95.55 kg/ha and 48.11, 48.20 and 48.15 kg/ha) recorded the maximum nitrogen uptake over rest of the treatment combinations The minimum nitrogen uptake by seed and straw was recorded in control (45.11, 45.33 and 45.22 kg/ha by seed and 22.96, 23.17 and 23.06 kg/ha by straw) during 2022-23, 2023-24 and in pooled analysis, respectively.

Table 4.16: Effect of sulphur levels and zinc application on N content and their uptake by seed and stover of gobhi sarson

Treatments	N content (%)						N uptake (kg/ha)					
	Seed			Stover			Seed			Stover		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Sulphur levels												
S_0-Control	2.935	2.945	2.940	0.595	0.599	0.597	55.56	56.68	56.12	27.30	27.56	27.43
S_1-10 kg/ha	3.135	3.142	3.139	0.633	0.639	0.636	66.01	66.48	66.25	32.34	32.91	32.63
S_2-20 kg/ha	3.266	3.269	3.268	0.661	0.667	0.664	75.27	75.67	75.47	37.07	37.91	37.49
S_3-30 kg/ha	3.310	3.316	3.313	0.676	0.672	0.674	79.02	80.30	79.66	41.12	41.11	41.11
SEm$\pm$	0.030	0.033	0.022	0.005	0.006	0.004	1.40	1.17	0.91	0.58	0.61	0.42
CD (P=0.05)	0.086	0.096	0.063	0.013	0.017	0.011	4.04	3.38	2.58	1.69	1.77	1.20
Zinc application												
Z_0-Control	2.938	2.941	2.939	0.596	0.598	0.597	52.53	53.53	53.03	27.13	27.42	27.27
Z_1-1 appl.	3.135	3.142	3.139	0.635	0.637	0.636	65.99	66.55	66.27	33.16	33.44	33.30
Z_2-2 appl.	3.262	3.267	3.265	0.664	0.669	0.667	77.01	77.75	77.38	38.17	38.72	38.44
Z_3-3 appl.	3.312	3.322	3.317	0.670	0.672	0.671	80.35	81.30	80.83	39.37	39.91	39.64
SEm$\pm$	0.030	0.033	0.022	0.005	0.006	0.004	1.40	1.17	0.91	0.58	0.61	0.42
CD (P=0.05)	0.086	0.096	0.063	0.013	0.017	0.011	4.04	3.38	2.58	1.69	1.77	1.20
CV (%)	4.08	4.55	3.46	3.14	4.04	2.89	8.79	7.25	6.44	7.35	7.61	5.99
Interaction SxZn												
CD (P=0.05)	NS	NS	NS	NS	NS	NS	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

Table 4.17 Interactiveeffects of sulphur levels and zinc application on N uptake in seed of gobhi sarson

Treatments	**2022-23**			
	S_0	S_1	S_2	S_3
Z_0	45.11	50.63	56.53	57.85
Z_1	56.68	63.78	70.96	72.54
Z_2	59.50	71.71	86.49	90.32
Z_3	60.97	77.93	87.10	95.39
SEm$\pm$	**2.80**			
CD (P=0.05)	**8.09**			
		2023-24		
	S_0	S_1	S_2	S_3
Z_0	45.33	50.84	56.69	61.29
Z_1	57.06	64.22	71.33	73.59
Z_2	60.99	72.33	87.07	90.60
Z_3	63.36	78.54	87.61	95.71
SEm$\pm$	**2.34**			
CD (P=0.05)	**6.75**			
		Pooled		
	S_0	S_1	S_2	S_3
Z_0	45.22	50.73	56.61	59.57
Z_1	56.87	64.00	71.15	73.06
Z_2	60.25	72.02	86.78	90.46
Z_3	62.16	78.23	87.35	95.55
SEm$\pm$	**1.82**			
CD (P=0.05)	**5.16**			

Table 4.18: Interactive effect of sulphur levels and zinc application on N uptake in stover of gobhi sarson

Treatments	**2022-23**			
	S_0	S_1	S_2	S_3
Z_0	22.96	25.55	29.28	30.72
Z_1	26.04	31.22	35.79	39.58
Z_2	29.83	35.78	41.01	46.05
Z_3	30.35	36.80	42.21	48.11
SEm$\pm$	**1.17**			
CD (P=0.05)	**3.38**			
		2023-24		
	S_0	S_1	S_2	S_3
Z_0	23.17	25.97	29.91	30.63
Z_1	26.21	31.66	36.46	39.43
Z_2	30.20	36.48	42.01	46.19
Z_3	30.64	37.55	43.26	48.20
SEm$\pm$	**1.23**			
CD (P=0.05)	**3.54**			
		Pooled		
	S_0	S_1	S_2	S_3
Z_0	23.06	25.76	29.60	30.67
Z_1	26.12	31.44	36.13	39.51
Z_2	30.02	36.13	41.51	46.12
Z_3	30.50	37.18	42.73	48.15
SEm$\pm$	**0.85**			
CD (P=0.05)	**2.40**			

4.4.3 Phosphorus content (%)

Sulphur levels

The information in table 4.19 shows that the amount of phosphorus in gobhi sarson seed and straw was significantly impacted by rising Sulphur levels. During 2022–2023 and 2023–2024, as well as in pooled study, the largest phosphorus was reported by Sulphur @ 30 kg/ha (S_3), which remained comparable to Sulphur @ 20 kg/ha (S_2).

Zinc impact

A comprehensive analysis of the data showed that the average mean and the usage of zinc in both years caused considerable variations in the phosphorus content of gobhi sarson seedling and straw. The zinc (Zn_3) treatment three had the highest phosphorus concentration compared to the other treatments, which stayed at the same level as Zn_2.

4.4.4 Phosphorus uptake (kg/ha)

Sulphur levels

The information in Table 4.19 makes it abundantly evident that different Sulphur concentrations.had a major effect on the amount of phosphorus that gobhi sarson seeds and straw could absorb. Applying Sulphur at a rate of 30 kg/ha (S_3) resulted in the highest phosphorus uptake of gobhi sarson (14.12, 14.37, and 14.25 kg/ha by seed and 12.14, 12.33, and 12.24 kg/ha by straw), which was determined to be noticeably better than the other treatments. In comparison to control (S0), sulphur @ 10 kg/ha (S1), and sulphur @ 20 kg/ha (S2), the percentage increase in phosphorus uptake resulting from the application of sulphur @ 30 kg/ha (S_3) was 45.11, 18.85, and 5.71 by seed and 59.38, 28.98, and 9.29 by straw. Additionally, these outcomes are consistentwith those of Kumar et al. (2018) and Tiwari et al. (2021).

Zinc application

Additional analysis of the information provided in Table 4.19 makes it abundantly evident that the treatment of zinc in both years and the averaged mean enhanced the absorption of Sulphur by the gobhi sarson seed and straw. The maximum phosphorus uptake of gobhi sarson was recorded with three spray of zinc (Zn_3) which was closely followed by two application of zinc (Zn_2) and proved significantly higher over control (Zn_0) and Zn_1. Three application of zinc (Zn_3) produced 56.50, 20.03; 54.64, 20.05 and 55.62, 20.08 percent by seed and 54.88, 23.06; 54.52, 22.42 and 54.70, 22.80 kg/ha by straw higher phosphorus uptake in the comparison control and Zn_1 during 2022-23, 2023-24 and in average mean, respectively.

Interaction

The information in Table 4.20 specify that the interaction effect of sulphur levels with application of zinc on phosphorus uptake of gobhi sarson have been found to be small in both years and the averaged mean. The treatment combination, sulphur @ 30 kg/ha with three application of zinc (S_3Zn_3) recorded the significantly maximum phosphorus uptake (17.04, 17.08 and 17.06 kg/ha by seed and 14.50, 14.72 and 14.61 kg/ha by straw).The lowest phosphorus uptake was recorded in S_0Zn_0 (7.70, 7.78 and 7.74 kg/ha by seed and 6.15, 6.26 and 6.21 kg/ha by straw) during 2022-23, 2023-24.

Table 4.19: Effect of sulphur levels and zinc application on P content and their uptake by seed and stover of gobhi sarson

Treatments	P content (%)						P uptake (kg/ha)					
	Seed			Stover			Seed			Stover		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Sulphur levels												
S_0-Control	0.512	0.516	0.514	0.166	0.168	0.167	9.70	9.94	9.82	7.63	7.74	7.68
S_1-10 kg/ha	0.566	0.569	0.568	0.183	0.186	0.185	11.93	12.05	11.99	9.37	9.60	9.49
S_2-20 kg/ha	0.582	0.584	0.583	0.197	0.199	0.198	13.43	13.53	13.48	11.07	11.33	11.20
S_3-30 kg/ha	0.591	0.593	0.592	0.199	0.201	0.200	14.12	14.37	14.25	12.14	12.33	12.24
SEm±	0.005	0.007	0.004	0.002	0.002	0.001	0.24	0.21	0.16	0.20	0.18	0.13
CD (P=0.05)	0.014	0.019	0.012	0.005	0.006	0.004	0.68	0.61	0.45	0.57	0.52	0.38
Zinc application												
Z_0-Control	0.512	0.514	0.513	0.166	0.169	0.167	9.15	9.37	9.26	7.58	7.74	7.66
Z_1-1 appl.	0.567	0.570	0.568	0.182	0.186	0.184	11.93	12.07	12.00	9.54	9.77	9.65
Z_2-2 appl.	0.583	0.587	0.585	0.197	0.199	0.198	13.77	13.96	13.87	11.36	11.53	11.45
Z_3-3 appl.	0.590	0.592	0.591	0.199	0.201	0.200	14.32	14.49	14.41	11.74	11.96	11.85
SEm±	0.005	0.007	0.004	0.002	0.002	0.001	0.24	0.21	0.16	0.20	0.18	0.13
CD (P=0.05)	0.014	0.019	0.012	0.005	0.006	0.004	0.68	0.61	0.45	0.57	0.52	0.38
CV (%)	3.77	5.00	3.55	4.14	4.41	3.42	8.30	7.33	6.26	8.49	7.58	6.43
Interaction SxZn												
CD (P=0.05)	NS.	NS.	NS.	NS.	NS.	NS.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

Table 4.20: Interactive effect of sulphur levels and zinc application on P uptake in seed of Gobhi sarson

Treatments	**2022-23**			
	S_0	S_1	S_2	S_3
Z_0	7.70	8.94	9.86	10.11
Z_1	10.04	11.70	12.84	13.15
Z_2	10.42	13.00	15.47	16.19
Z_3	10.64	14.08	15.53	17.04
SEm$\pm$	**0.47**			
CD (P=0.05)	**1.36**			
		2023-24		
	S_0	S_1	S_2	S_3
Z_0	7.78	9.02	9.92	10.74
Z_1	10.15	11.81	12.94	13.36
Z_2	10.75	13.17	15.64	16.29
Z_3	11.08	14.19	15.61	17.08
SEm$\pm$	**0.42**			
CD (P=0.05)	**1.22**			
		Pooled		
	S_0	S_1	S_2	S_3
Z_0	7.74	8.98	9.89	10.42
Z_1	10.10	11.75	12.89	13.26
Z_2	10.58	13.08	15.56	16.24
Z_3	10.86	14.13	15.57	17.06
SEm$\pm$	**0.32**			
CD (P=0.05)	**0.90**			

Table 4.21: Interactive effect of sulphur levels and zinc application on P uptake in stover of gobhi sarson

Treatments	**2022-23**			
	S_0	S_1	S_2	S_3
Z_0	6.15	7.09	8.38	8.68
Z_1	7.18	8.92	10.54	11.51
Z_2	8.51	10.58	12.50	13.87
Z_3	8.67	10.90	12.88	14.50
SEm±	**0.39**			
CD (P=0.05)	**1.14**			
		2023-24		
	S_0	S_1	S_2	S_3
Z_0	6.26	7.28	8.60	8.83
Z_1	7.32	9.18	10.84	11.75
Z_2	8.60	10.78	12.73	14.03
Z_3	8.77	11.16	13.18	14.72
SEm±	**0.36**			
CD (P=0.05)	**1.04**			
		Pooled		
	S_0	S_1	S_2	S_3
Z_0	6.21	7.19	8.49	8.75
Z_1	7.25	9.05	10.69	11.63
Z_2	8.56	10.68	12.61	13.95
Z_3	8.72	11.03	13.03	14.61
SEm±	**0.27**			
CD (P=0.05)	**0.75**			

4.4.5: Potassium Content (%):

An analysis of the results in Table 4.22 shows that the application of sulphur significantly influenced potassium content by gobhi sarson seed and stover across both years and in the pooled analysis.

Sulphur Levels:

The information in Table 4.22 makes it abundantly evident that rising sulphur levels have an immeNSe effect on the amount of potassium of gobhi sarson seedling and straw. The sulphur @ 30 kg/ha (S_3) recorded the maximum potassium content during 2022-23 and 2023-24 and in pooled analysis, proved superior over control.

- **Year 2022–2023:** The application of sulphur at 30 kg/ha (S_3) resulted in the highest potassium content in seeds (0.581%) and stover (1.671%), while the control (S_0) had the lowest potassium content in seeds (0.457%) and stover (1.366%).
- **Year 2023–2024:** Similarly, S_3 exhibited the highest potassium content in seeds (0.610%) and stover (1.641%), whereas the control (S_0) had the lowest potassium content in seeds (0.424%) and stover (1.230%).
- **Pooled Analysis**: Over the two years, S_3 maintained the highest potassium content in seeds (0.596%) and stover (1.651%), with the lowest values recorded in the control (S_0) for seeds (0.441%) and stover (1.298%).

For Zinc Application: An in-depth investigation of the data identified that the application of zinc in both years and in the average mean analysis caused a considerable variation in the potassium content of gobhi sarson seed and straw. In the two studies, the treatment three implication of zinc (Zn_3) had the highest potassium concentration compared to the other treatments, which stayed at par with Zn_2.

- **Year 2022–2023:** The zinc treatment with three applications (Zn_3) recorded the highest potassium content in seeds (0.588%) and stover (1.624%), while the control (Z_0) had the lowest potassium content in seeds (0.468%) and stover (1.322%).

- **Year 2023–2024:** Similar trends were observed, with Zn_3 achieving the highest potassium content in seeds (0.591%) and stover (1.642%) and Z_0 the lowest in seeds (0.437%) and stover (1.281%).
- **Pooled Analysis:** Zn_3 treatment resulted in the highest potassium content in seeds (0.589%) and stover (1.633%), while Z_0 recorded the lowest values for seeds (0.452%) and stover (1.301%).

4.4.6: Potassium uptake (kg/ha)

Sulphur Levels

An analysis of the results in Table 4.22 shows that the application of sulphur significantly influenced potassium uptake by gobhi sarson seed and stover across both years and in the pooled analysis.

- **Year 2022–2023:** The usage of sulphur at 30 kg/ha (S_3) recorded the highest potassium uptake in seeds (13.78 kg/ha) and stover (101.10 kg/ha), while the control (S_0) showed the lowest uptake in seeds (8.62 kg/ha) and stover (62.48 kg/ha).
- **Year 2023–2024:** Similarly, S_3 exhibited the highest potassium uptake in seeds (14.68 kg/ha) and stover (99.80 kg/ha), with the control (S_0) showing the lowest values in seeds (8.13 kg/ha) and stover (56.40 kg/ha).
- **Pooled Analysis:** In the combined analysis, S_3 maintained the highest uptake in seeds (14.23 kg/ha) and stover (100.45 kg/ha), outperforming all other treatments. The control treatment (S_0) had the lowest uptake in seeds (8.375 kg/ha) and stover (50.44 kg/ha).

These conclusions are consistent with those of Tiwari et al. (2021) and Kumar et al. (2018), which report that higher sulphur levels enhance potassium uptake in crops due to improved nutrient availability and utilization efficiency.

Zinc Application

The application of zinc also significantly influenced potassium uptake .

- **Year 2022–2023:** The three application of zinc (Zn_3) resulted in the highest potassium uptake in seeds (14.18 kg/ha) and stover (94.85 kg/ha), while the control treatment (Z_0) had the lowest uptake in seeds (8.34 kg/ha) and stover (60.01 kg/ha).

- **Year 2023–2024:** Zn_3 again recorded the highest potassium uptake in seeds (14.39 kg/ha) and stover (96.96 kg/ha), with the control (Z_0) exhibiting the lowest uptake in seeds (7.93 kg/ha) and stover (58.56 kg/ha).
- **Pooled Analysis:** Over the two years, the Zn_3 treatment achieved the highest uptake in seeds (14.28 kg/ha) and stover (95.90 kg/ha), while the control treatment had the lowest uptake in seeds (8.13 kg/ha) and stover (59.28 kg/ha).

These results highlight the critical role of zinc in enhancing potassium absorption, as corroborated by previous studies emphasizing zinc's effect on root activity and nutrient assimilation.

Interaction

According to the findings (Tables 4.23 and 4.24), applying of zinc to gobhi sarson has an interaction impact with sulphur levels. Significantly greater potassium absorption by seed and straw was seen in the treatment combination of sulphur @ 30 kg/ha with three application of zinc (S_3Zn_3) compared to the other treatment combinations

Table 4.22: Impact of sulphur levels and zinc application on K content and their uptake by seed and stover of gobhi sarson

Treatments	K content (%)						K uptake (kg/ha)					
	Seed			Stover			Seed			Stover		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Sulphur levels												
S_0-Control	0.457	0.424	0.441	1.366	1.230	1.298	8.62	8.13	8.375	62.48	56.40	59.44
S_1-10 kg/ha	0.526	0.474	0.500	1.541	1.405	1.473	11.01	9.97	10.49	78.39	72.04	75.21
S_2-20 kg/ha	0.570	0.590	0.580	1.642	1.578	1.623	13.06	13.58	13.32	91.57	89.29	90.43
S_3-30 kg/ha	0.581	0.610	0.596	1.671	1.641	1.651	13.78	14.68	14.23	101.10	99.80	100.45
SEm±	0.011	0.012	0.008	0.029	0.029	0.019	0.87	0.85	0.57	3.67	3.54	2.82
CD (P=0.05)	0.033	0.034	0.021	0.085	0.086	0.053	2.61	2.53	1.53	10.57	10.42	7.23
Zinc application												
Z_0-Control	0.468	0.437	0.452	1.322	1.281	1.301	8.34	7.93	8.13	60.01	58.56	59.28
Z_1-1 appl.	0.544	0.547	0.546	1.454	1.477	1.465	11.42	11.55	11.48	75.84	77.14	76.49
Z_2-2 appl.	0.577	0.591	0.584	1.593	1.642	1.617	13.54	13.99	13.76	91.05	94.51	92.78
Z_3-3 appl.	0.588	0.591	0.589	1.624	1.642	1.633	14.18	14.39	14.28	94.85	96.96	95.90
SEm±	0.012	0.013	0.008	0.029	0.031	0.032	0.81	0.86	0.54	3.44	3.29	2.61
CD (P=0.05)	0.034	0.039	0.019	0.088	0.092	0.094	2.52	2.59	1.47	10.22	9.81	7.43
CV (%)	4.23	4.46	3.42	3.18	4.12	3.72	8.42	7.64	6.82	7.31	7.41	6.83
Interaction SxZn												
CD (P=0.05)	NS	NS	NS	NS	NS	NS	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

Table 4.23: Interactive effects of Sulphur levels and zinc application on K uptake in seed of gobhi sarson

Treatments	**2022-23**			
	S_0	S_1	S_2	S_3
Z_0	6.13	7.95	9.49	10.98
Z_1	7.98	9.37	11.08	12.49
Z_2	9.36	10.81	12.96	14.87
Z_3	10.64	13.08	15.69	15.98
SEm±	**0.43**			
CD (P=0.05)	**1.25**			
	2023-24			
	S_0	S_1	S_2	S_3
Z_0	6.47	7.98	9.62	11.23
Z_1	7.85	9.43	11.21	12.56
Z_2	9.31	10.78	12.44	13.91
Z_3	10.91	12.56	13.98	15.59
SEm±	**0.41**			
CD (P=0.05)	**1.23**			
	Pooled			
	S_0	S_1	S_2	S_3
Z_0	6.12	7.62	9.13	10.56
Z_1	7.53	8.94	10.52	11.94
Z_2	8.97	10.31	11.88	13.35
Z_3	10.36	11.64	12.98	14.72
SEm±	**0.38**			
CD (P=0.05)	**1.16**			

Table 4.24: Interactive effects of sulphur levels and zinc application on K uptake in stover of gobhi sarson

Treatments	2022-23			
	S_0	S_1	S_2	S_3
Z_0	61.22	72.22	81.43	90.56
Z_1	73.24	82.41	92.57	103.81
Z_2	84.56	93.66	105.23	116.22
Z_3	95.17	104.22	115.52	117.62
SEm±	**2.34**			
CD (P=0.05)	**8.01**			
2023-24				
	S_0	S_1	S_2	S_3
Z_0	60.58	71.51	82.56	93.67
Z_1	72.77	82.41	93.57	101.32
Z_2	83.47	95.14	104.08	113.98
Z_3	94.63	103.23	114.81	116.02
SEm±	**2.38**			
CD (P=0.05)	**8.02**			
	Pooled			
	S_0	S_1	S_2	S_3
Z_0	60.78	69..51	78.33	89.11
Z_1	71.13	82 .51	90.41	99.43
Z_2	79.67	88.51	99.56	109.55
Z_3	87.51	96.32	109.22	115. 1
SEm±	**2.23**			
CD (P=0.05)	**7.23**			

4.4.7 Zinc content (mg/g)

Sulphur levels

The values shown in Table 4.25 unequivocally show that the zinc concentration of Gobhi sarson seed and straw was significantly impacted by sulphur levels. In 2022–2023 and 2023–2024, the sulphur @ 30 kg/ha (S3) recorded a considerably greater zinc content in seedling and straw. In both years and the averaged mean, the S_3 treatment outperformed the other treatments (except from the S_2 treatment) in average analysis. These conclusions are consistent with those of Zizala et al. (2008) and Verma et al. (2012), who similarly discovered that applying 45 kg/ha of sulphur increased the zinc concentration.

Zinc application

A rigorous study of the data showed that the zinc treatment in both years and in the pooled analysis caused a considerable variation in the zinc content of gobhi sarson seed and straw. In both years in the combined study, the zinc concentration under treatment three was considerably greater than that of the other treatments, with zinc (Zn_3) remaining on par with Zn_2. These findings are consistent with those of Deo and Khandelwal et al. (2009) and Zizala et al. (2008), who found that graiNS could only absorb up to 5 kg of zinc per hectare.

4.4.8 Zinc uptake (g/ha)

Sulphur levels

A review of the data (Table 4.25) demonstrated that rising sulphur levels had a major impact on seedling and straw's absorption of zinc in 2022–2023 and 2023–2024 as well as in combined analysis. Both years and the combined data showed that the treatment sulphur at 30 kg/ha (S3) increased by 49.71, 48.33, and 49.03 percent and 68.20, 68.10, and 68.17 percent over control, respectively. The results are consistent with those of Sharma et al. (2009), who found that applying 45 kg/ha of Sulphur increased zinc absorption.

Zinc application

Additionally, data showed that zinc administration significantly boosted seed and straw zinc absorption compared to control. Zinc application (three zinc application) reported the highest zinc absorption by seedling and straw in 2022–2023 and 2023–2024, and the combined mean was noticeably better than the other treatments. Three doses of zinc (Zn3) increased the amount of Sulphur absorption by seedling and straw by 61.64, 60.02, and

60.81 percent and 62.29, 63.12, and 62.71 percent above control, respectively, in both years in pooled analysis. According to Verma et al. (2012), Deo and Khandelwal et al. (2009), and Zizala et al. (2008), zinc absorption by grains was shown to be up to 5 kg Zn/ha.

Interaction

Table 4.26 and 4.27 clearly demonstrates that the interaction effect of sulphur levels with application of zinc of gobhi sarson was determined to be influential in the combined analysis throughout the years. The treatment combination, sulphur @ 30 kg/ha with three implications.of zinc (106.95, 107.03 and 106.99 g/ha and 202.58, 204.58 and 203.58 g/ha) recorded. The minimum sulphur uptake was recorded in control (45.60, 46.02 and 45.81 g/ha and 77.80, 78.21 and 78.01 g/ha) during 2022-23, 2023-24 and in pooled analysis, respectively.

4.4.9 Sulphur content (%)

Sulphur levels

Table 4.2 makes it abundantly evident that rising Sulphur levels have a major impact on the amount of sulphur in gobhi sarson seed and straw. The highest sulphur concentration in seedling and straw was reported by S_3 at 30 kg/ha. This level was comparable to S_2 in 2022–2023 and 2023–2024, and in both years' averaged and mean analyses. The results are consistent with the outcomes of BaNSal et al. (2000) and Sharma et al. (2009), who indicated that the rise in S content and yield may account for the increase in S absorption with Sulphur treatment.

Zinc application

According to a rigorous analysis of the data, the usage of zinc caused a considerable variation in the sulphur content of gobhi sarson seed and straw. The highest amount of sulphur was found under treatment three of zinc (Zn_3) compared to the other treatments in both years and combined analysis, which stayed at the same level as Zn_2. Verma et al. (2012) and Zizala et al. (2008) indicated that grains could only absorb up to 5 kg of zinc per hectare, which is in close agreement with these findings.

4.4.10 Sulphur uptake (kg/ha)

Sulphur sources

It is evident from Tables 4.29 and 4.30 that rising sulphur levels had a major impact on the absorption of sulphur by seed and straw in both years. In both years, as well as in the pooled data, the largest sulphur absorption by seed and straw was reported by Sulphur @ 30 kg/ha (S3), which indicated a rise of 44.00, 44.06, and 44.03 percent and 65.67, 66.05, and 65.86 percent over control, respectively. Higher sulphur content in the seed and stover as well as higher seed and stover yields may be the cause of the increased sulphur absorption by mustard treated with sulphur. The results are consistent with those of Bansal et al. (2000), who found that Sulphur increased S uptake.

Zinc application

An analysis of the data additionally demonstrated that, in both years, the use of zinc treatments significantly boosted the absorption of Sulphur by seed and straw compared to the control. Zinc (Zn3) application was shown to maximize sulphur absorption by seedlings and straw in 2022–23 and 2023–24 and pooled mean proved significantly superior over rest of the treatments. Sulphur uptake by seed and straw due to three application of zinc (Zn3) was to the extent of 54.64, 53.90 and 54.29 percent and 59.93, 59.16 and 59.56 percent over control, respectively during both the years as well as average mean analysis.The findings are in close acceptance to Verma et al. (2012) Zizala et al. (2008) and Babhulkar et al. (2000) which found sulphur absorption by grains only upto 5 kg Zn/ha.

Interaction

Tables 4.29 and 4.30 make it abundantly evident how the application of zinc and sulphur interact to affect the absorption of sulphur by gobhi sarson seeds and straw. Sulphur absorption by seedling and straw was considerably greater in the treatment combination of sulphur @ 30 kg/ha with three application of zinc (S3Zn3) (26.16, 26.44, and 26.30 kg/ha and 35.93, 36.65, and 36.29 kg/ha) than in any of the other treatment choices.

Table 4.25: Effect of sulphur levels and zinc application on Zn content and their uptake by seed and stover of gobhi sarson

Treatments	Zn content (mg/g)						Zn uptake (g/kg)					
	Seed			Stover			Seed			Stover		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Sulphur levels												
S_0-Control	30.75	30.98	30.87	21.62	21.74	21.68	58.30	59.73	59.01	99.45	100.28	99.86
S_1-10 kg/ha	33.69	33.89	33.79	24.68	24.88	24.78	71.11	71.87	71.49	126.57	128.65	127.61
S_2-20 kg/ha	36.15	36.26	36.21	26.86	26.98	26.92	83.55	84.17	83.86	151.22	153.96	152.59
S_3-30 kg/ha	36.44	36.49	36.47	27.35	27.43	27.39	87.28	88.60	87.94	167.18	168.67	167.93
SEm$\pm$	0.32	0.30	0.22	0.27	0.25	0.18	1.63	1.61	1.14	2.84	2.92	2.04
CD (P=0.05)	0.91	0.86	0.61	0.77	0.73	0.52	4.70	4.64	3.23	8.20	8.43	5.76
Zinc application												
Z_0-Control	30.71	30.83	30.77	21.77	21.81	21.79	54.98	56.18	55.58	99.39	100.27	99.83
Z_1-1 appl.	33.64	33.88	33.76	24.62	24.81	24.72	70.89	71.83	71.36	129.12	130.81	129.96
Z_2-2 appl.	36.13	36.26	36.19	26.79	27.00	26.89	85.50	86.46	85.98	154.61	156.93	155.77
Z_3-3 appl.	36.55	36.66	36.60	27.33	27.41	27.37	88.87	89.90	89.38	161.30	163.56	162.43
SEm$\pm$	0.32	0.30	0.22	0.27	0.25	0.18	1.63	1.61	1.14	2.84	2.92	2.04
CD (P=0.05)	0.91	0.86	0.61	0.77	0.73	0.52	4.70	4.64	3.23	8.20	8.43	5.76
CV (%)	4.00	3.73	3.09	4.62	4.33	3.58	9.39	9.14	7.41	9.03	9.16	7.28
Interaction SxZn												
CD (P=0.05)	NS	NS	NS	NS	NS	NS	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

Table 4.26: Interactiveeffects of sulphur levels and zinc application on Zn uptake in seed of gobhi sarson

Treatments	**2022-23**			
	S_0	S_1	S_2	S_3
Z_0	45.60	52.49	60.38	61.45
Z_1	58.81	67.88	77.79	79.09
Z_2	63.72	78.77	97.86	101.64
Z_3	65.05	85.29	98.19	106.95
SEm±	**3.26**			
CD (P=0.05)	**9.40**			
2023-24				
	S_0	S_1	S_2	S_3
Z_0	46.02	52.92	60.69	65.09
Z_1	59.60	68.77	78.55	80.40
Z_2	65.55	79.72	98.68	101.87
Z_3	67.73	86.08	98.74	107.03
SEm±	**3.21**			
CD (P=0.05)	**9.28**			
Pooled				
	S_0	S_1	S_2	S_3
Z_0	45.81	52.71	60.53	63.27
Z_1	59.21	68.33	78.17	79.75
Z_2	64.64	79.25	98.27	101.76
Z_3	66.39	85.68	98.47	106.99
SEm±	**2.29**			
CD (P=0.05)	**6.47**			

Table 4.27: Interactive effects of sulphur levels and zinc application on Zn uptake in stover of gobhi sarson

Treatments	**2022-23**			
	S_0	S_1	S_2	S_3
Z_0	77.80	92.89	110.96	115.90
Z_1	93.62	120.47	143.91	158.48
Z_2	111.58	143.58	171.52	191.78
Z_3	114.79	149.35	178.50	202.58
SEm±	**5.68**			
CD (P=0.05)	**16.40**			
2023-24				
	S_0	S_1	S_2	S_3
Z_0	78.21	94.05	112.54	116.28
Z_1	94.49	122.43	146.49	159.84
Z_2	112.77	146.12	174.84	193.99
Z_3	115.64	152.03	181.99	204.58
SEm±	**5.84**			
CD (P=0.05)	**16.86**			
Pooled				
	S_0	S_1	S_2	S_3
Z_0	78.01	93.47	111.75	116.09
Z_1	94.05	121.45	145.20	159.16
Z_2	112.17	144.85	173.18	192.88
Z_3	115.22	150.69	180.24	203.58
SEm±	**4.07**			
CD (P=0.05)	**11.52**			

Table 4.28: Effect of sulphur levels and zinc application on S content and their uptake by seed and stover of gobhi sarson

Treatments	S content (%)						S uptake (kg/ha)					
	Seed			Stover			Seed			Stover		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Sulphur levels												
S_0-Control	0.792	0.796	0.794	0.392	0.398	0.395	15.00	15.33	15.16	18.03	18.35	18.19
S_1-10 kg/ha	0.844	0.849	0.847	0.444	0.449	0.447	17.78	17.98	17.88	22.76	23.20	22.98
S_2-20 kg/ha	0.892	0.899	0.896	0.481	0.488	0.485	20.57	20.83	20.70	27.07	27.83	27.45
S_3-30 kg/ha	0.904	0.911	0.908	0.489	0.496	0.493	21.60	22.08	21.84	29.87	30.47	30.17
SEm±	0.007	0.009	0.006	0.004	0.005	0.003	0.41	0.35	0.27	0.51	0.46	0.34
CD (P=0.05)	0.022	0.026	0.017	0.011	0.014	0.009	1.19	1.00	0.76	1.48	1.33	0.98
Zinc application												
Z_0-Control	0.792	0.795	0.794	0.394	0.401	0.397	14.17	14.49	14.33	17.97	18.44	18.20
Z_1-1 appl.	0.846	0.852	0.849	0.444	0.451	0.447	17.82	18.06	17.94	23.27	23.75	23.51
Z_2-2 appl.	0.891	0.897	0.894	0.481	0.487	0.484	21.04	21.35	21.20	27.76	28.30	28.03
Z_3-3 appl.	0.903	0.911	0.907	0.487	0.492	0.490	21.91	22.30	22.11	28.74	29.35	29.04
SEm±	0.007	0.009	0.006	0.004	0.005	0.003	0.41	0.35	0.27	0.51	0.46	0.34
CD (P=0.05)	0.022	0.026	0.017	0.011	0.014	0.009	1.19	1.00	0.76	1.48	1.33	0.98
CV (%)	3.78	4.51	3.33	3.81	4.57	3.37	9.51	7.90	6.98	9.11	7.98	6.84
Interaction SxZn												
CD (P=0.05)	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig.	N.Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.

Table 4.29: Interactive effect of sulphur levels and zinc application on S uptake in seed of gobhi sarson

Treatments	**2022-23**			
	S_0	S_1	S_2	S_3
Z_0	12.10	13.55	15.35	15.70
Z_1	15.22	17.08	19.28	19.71
Z_2	16.15	19.42	23.77	24.82
Z_3	16.52	21.07	23.89	26.16
SEm$\pm$	**0.82**			
CD (P=0.05)	**2.38**			
2023-24				
	S_0	S_1	S_2	S_3
Z_0	12.15	13.63	15.47	16.70
Z_1	15.35	17.27	19.52	20.12
Z_2	16.59	19.67	24.10	25.05
Z_3	17.22	21.34	24.22	26.44
SEm$\pm$	**0.69**			
CD (P=0.05)	**2.01**			
Pooled				
	S_0	S_1	S_2	S_3
Z_0	12.13	13.59	15.41	16.20
Z_1	15.28	17.18	19.40	19.91
Z_2	16.37	19.55	23.93	24.93
Z_3	16.87	21.20	24.06	26.30
SEm$\pm$	**0.54**			
CD (P=0.05)	**1.52**			

Table 4.30: Interactive effects of sulphur levels and zinc application on S uptake in stover of gobhi sarson

Treatments	2022-23			
	S_0	S_1	S_2	S_3
Z_0	14.20	16.82	20.00	20.85
Z_1	17.03	21.75	25.86	28.43
Z_2	20.22	25.82	30.70	34.28
Z_3	20.65	26.65	31.71	35.93
SEm$\pm$	**1.03**			
CD (P=0.05)	**2.97**			
	2023-24			
	S_0	S_1	S_2	S_3
Z_0	14.53	17.22	20.65	21.34
Z_1	17.34	22.14	26.55	28.97
Z_2	20.55	26.25	31.48	34.92
Z_3	20.97	27.18	32.61	36.65
SEm$\pm$	**0.92**			
CD (P=0.05)	**2.66**			
	Pooled			
	S_0	S_1	S_2	S_3
Z_0	14.36	17.02	20.33	21.10
Z_1	17.19	21.95	26.21	28.70
Z_2	20.39	26.04	31.09	34.60
Z_3	20.81	26.92	32.16	36.29
SEm$\pm$	**0.69**			
CD (P=0.05)	**1.95**			

4.5 Economics of Gobhi sarson

4.5.1 Effect of Sulphur: The data presented in Tables 4.31 and 4.32 clearly demonstrate that sulphur application significantly enhanced the net returns and benefit-cost (B:C) ratio of Gobhi Sarson across both experimental years and the pooled mean. The highest pooled mean net returns of ₹86,257 per hectare and a B:C ratio of 2.03 were observed with the application of sulphur at 30 kg/ha (S_3). This was closely followed by the treatment with 20 kg/ha of sulphur (S_2).

4.5.2 Impact of Zinc: An examination of Tables 4.31 and 4.32 indicates that the application of zinc (Z_3: three application) resulted in substantially higher net returns and B:C ratios compared to the control and other zinc treatments during both years, as well as in the pooled analysis. The highest pooled mean net returns of ₹87,786 per hectare and a B:C ratio of 2.06 were achieved with the Z_3 treatment, highlighting its superior economic performance.

Table 4.31:Effect of zinc levels and sulphur application on gross Returns and cost of cultivation of gobhi sarson.

	Gross return (Rs/ha)			Cost of cultivation (Rs/ha)		
Sulphur levels	**2022-23**	**2023-24**	**Pooled**	**2022-23**	**2023-24**	**Pooled**
S_0-Control	97543	106780	102161	38756	38913	38834
S_1-10 kg/ha	108297	117272	112784	39910	40124	40017
S_2-20 kg/ha	118496	128259	123377	40987	41189	41088
S_3-30 kg/ha	122786	134230	128508	42117	42384	42250
Zinc application						
Z_0-Control	92342	101167	96754	38756	38913	38834
Z_1-1 appl.	108650	117708	113179	39950	40174	40062
Z_2-2 appl.	120974	131906	126440	41120	41339	41229
Z_3-3 appl.	124750	135712	130231	42411	42478	42444

Table 4.32: Effect of zinc levels and sulphur application on net returns and B:C ratio of gobhi sarson.

	Net returns (Rs/ha)			B:C ratio		
Sulphur levels	**2022-23**	**2023-24**	**Pooled**	**2022-23**	**2023-24**	**Pooled**
S_0-Control	58787	67867	63327	1.51	1.74	1.62
S_1-10 kg/ha	68387	77140	72763	1.71	1.92	1.81
S_2-20 kg/ha	77509	87070	82279	1.89	2.11	2.00
S_3-30 kg/ha	80669	91846	86257	1.91	2.16	2.03
Zinc application						
Z_0-Control	53586	62254	57920	1.38	1.59	1.488
Z_1-1 appl.	68700	77534	73117	1.71	1.92	1.81
Z_2-2 appl.	79854	90567	85210	1.94	2.19	2.06
Z_3-3 appl.	82339	93234	87786	1.94	2.19	2.06

Chapter - 5

Summary and Conclusion

The study, executed on various aspects of the experiment entitled "**Effect of Different Levels of Sulphur and Zinc on Growth, Yield, and Quality Attributes of Gobhi Sarson (*Brassica napus* L.)"** is comprehensively summarized. The experiment was conducted on Gobhi Sarson (GSC-7) using a Factorial Randomized Block Design with 16 treatments, 3 replications, and 48 plots. The treatments included varying levels of sulphur (S_0, S_1, S_2, S_3) and zinc (Z_0, Z_1, Z_2, Z_3) applied at different stages. The variety GSC-7, developed by Punjab Agricultural University in 2015, was used in the present study. The seed rate was 5 kg/ha with a spacing of 45 cm x 10 cm. Sulphur (S_0 to S_3) applied as basal doses in amounts ranging from 10 to 30 kg/ha. Zinc was applied as Zinc EDTA 12%, while Sulphur was applied in the form of Bentonite Sulphur 90%. This chapter also presents the desired conclusion drawn from the experiment's findings.

5.1 Impact of sulphur

5.1.1 The application of Sulphur at 30 kg/ha (S_3) was associated with a substantially larger crop height as well as dry mater accumulation at 30, 60, 90, 120 DAS, and at mustard harvest when compared with the other treatments in the two-year and combined analysis.

5.1.2 With the introduction of sulphur @ 30 kg/ha (S_3), which was closely followed by sulphur @ 20 kg/ha (S2), notable maximum fresh and dried weight, total number of leaf per plant, leaf area Index , and the number of branches per plant of mustard (30, 60, 90, 120 DAS and at harvest) were observed.

5.1.3 Sulphur levels rise repeatedly at a rate of 30 kg/ha (S_3), increased leaf area index of gobhi sarson significantly when compared with the other treatments in the two-year and combined analysis.

5.1.4 Relative to all other treatments, the number of siliqua/plant, seeds/siliqua, and specimen weight of gobhi sarson grew considerably with sulphur @ 30 kg/ha (S3).

5.1.5 Compared to the other treatments, the usage of 30 kg/ha of Sulphur (S_3) was comparable to that of 20 kg/ha of sulphur (S2) and resulted in a considerably greater seed, which is straw, and biological production of gobhi sarson.

5.1.6 The findings suggested that applying a dose of 30 kg/ha of Sulphur resulted in a considerably increased absorption of NPK Zn S in gobhi sarson seed and straw compared to the control.

5.1.7 The protein and oil content of grain and the oil production of gobhi sarson were much higher than control (S_0) when sulphur levels (S_3) were raised successively.

5.2 Application of zinc

5.2.1 Three application of zinc (Zn_3) which was followed by two application of zinc (Zn_2), recorded significantly the highest plant height, The number of mustard branches per plant, both fresh and dried weight, leaf surface index, and the quantity of leaves per plant at 30, 60, 90, and 120 DAS, as well as at harvest for the remaining treatments.

5.2.2 In comparison to all other treatments, the usage of three zinc (Zn_3) sprays resulted in the greatest increase in the number of siliqua/plant, seeds/siliqua, and the experiment weight of gobhi sarson.

5.2.3 Significant improvement was noted in with three spray of zinc (Zn3) recorded significantly maximum seed, straw, biological yield of gobhi sarson as compared to rest of the treatments.

5.2.4 Three application of zinc (Zn3) which was followed by Zn_2 and recorded significantly the highest NPK Zn S Uptake in both seeds and stover productivity of gobhi sarson.

5.2.5 It was uncovered that by three application of zinc (Zn_0) recorded significantly higher oil content of gobhi sarson in the comparison to control.

Interaction

5.3.1 The highest seed, straw and biological yield was attained by treatment combination of sulphur @ 30 kg/ha with three application of zinc (S_3Zn_3)

5.3.2 NPK Zn S uptake by seed and stover attained maximum under treatment S_3Zn_3 and proved significantly superior during pooled analysis.

Conclusion

From the present study, it may be concluded that application of 30 kg of sulfur per hectare together with three applications of zinc (Zinc EDTA 12% @ 0.5 g/L at 15, 45 and 75 DAS) significantly improved the productivity of gobhi sarson in Punjab conditions. However, further studies are required for confirmation of consistency of the results before making any final recommendations.

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Appendix - I

Analysis of variance for plant height at different stages of gobhi sarson

At 30 DAS 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.48	0.238	0.424513	NS
Z	3	38.56448	12.855	22.90656	**
S	3	48.0921	16.031	28.56578	**
ZxS	9	0.27	0.031	0.054411	NS
Error	30	16.84	0.561		

At 30 DAS 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.85	0.427	0.47979	NS
Z	3	37.02161	12.341	13.87685	**
S	3	48.9612	16.320	18.35218	**
ZxS	9	0.27	0.029	0.033123	NS
Error	30	26.68	0.889		

At 30 DAS pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	0.144	0.144	0.199	NS
Rep /year	4	1.330	0.332	0.458	NS
Z	3	75.571	25.190	34.734	**
Y x Z	3	0.015	0.005	0.007	NS
S	3	97.028	32.343	44.596	**
Y x S	3	0.026	0.009	0.012	NS
Z x S	9	0.540	0.060	0.083	NS
YxZxS	9	0.000	0.000	0.000	NS
Error	60	43.514	0.725		

**Significant at 5% level

Appendix - II

Analysis of variance for plant height at different stages of gobhi sarson

At 60 DAS 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	20.93	10.466	1.566995	NS
Z	3	288.8967	96.299	14.41788	**
S	3	166.1234	55.374	8.290672	**
ZxS	9	0.47	0.052	0.007763	NS
Error	30	200.37	6.679		

At 60 DAS 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	21.18	10.592	1.42919	NS
Z	3	284.24	94.747	12.78414	**
S	3	184.3833	61.461	8.292926	**
ZxS	9	0.50	0.056	0.00756	NS
Error	30	26.68	0.889		

At 60 DAS pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	1.426	1.426	0.202	NS
Rep /year	4	42.117	10.529	1.495	NS
Z	3	573.065	191.022	27.114	**
Y x Z	3	0.072	0.024	0.003	NS
S	3	350.264	116.755	16.572	**
Y x S	3	0.243	0.081	0.011	NS
Z x S	9	0.970	0.108	0.015	NS
YxZxS	9	0.000	0.000	0.000	NS
Error	60	422.712	7.045		

**Significant at 5% level

Appendix - III

At 90 DAS 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	111.13	55.567	0.760421	NS
Z	3	6250.282	2083.427	28.51104	**
S	3	3080.414	1026.805	14.0515	**
ZxS	9	24.04	2.671	0.036554	NS
Error	30	2192.23	73.074		

At 90 DAS 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	96.27	48.137	0.599786	NS
Z	3	6272.565	2090.855	26.05218	**
S	3	3313.634	1104.545	13.76269	**
ZxS	9	25.58	2.842	0.035413	NS
Error	30	2407.69	80.256		

At 90 DAS pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	21.206	21.206	0.277	NS
Rep /year	4	207.408	51.852	0.676	NS
Z	3	12521.813	4173.938	54.444	**
Y x Z	3	1.035	0.345	0.005	NS
S	3	6391.129	2130.376	27.788	**
Y x S	3	2.920	0.973	0.013	NS
Z x S	9	49.598	5.511	0.072	NS
YxZxS	9	0.022	0.002	0.000	NS
Error	60	4599.925	76.665		

**Significant at 5% level

Appendix - IV

At 120 DAS 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	308.60	154.298	1.447105	NS
Z	3	6959.22	2319.740	21.75593	**
S	3	4149.866	1383.289	12.97332	**
ZxS	9	28.64	3.182	0.029845	NS
Error	30	3198.77	106.626		

At 120 DAS 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	396.58	198.289	1.774903	NS
Z	3	6736.786	2245.595	20.10053	**
S	3	4162.372	1387.457	12.41926	**
ZxS	9	27.44	3.049	0.027289	NS
Error	30	3351.55	111.718		

At 120 DAS pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	22.815	22.815	0.209	NS
Rep /year	4	705.175	176.294	1.615	NS
Z	3	13694.807	4564.936	41.814	**
Y x Z	3	1.199	0.400	0.004	NS
S	3	8312.041	2770.680	25.379	**
Y x S	3	0.197	0.066	0.001	NS
Z x S	9	56.069	6.230	0.057	NS
YxZxS	9	0.009	0.001	0.000	NS
Error	60	6550.316	109.172		

**Significant at 5% level

Appendix - V

At harvest 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	696.05	348.025	2.538341	NS
Z	3	10865.07	3621.689	26.41501	**
S	3	10790.04	3596.679	26.2326	**
ZxS	9	97.02	10.780	0.078625	NS
Error	30	4113.22	137.107		

At harvest 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	531.30	265.650	1.653842	NS
Z	3	11424.14	3808.048	23.70753	**
S	3	10809.34	3603.114	22.43168	**
ZxS	9	100.79	11.199	0.069718	NS
Error	30	4818.78	160.626		

At harvest pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	29.305	29.305	0.197	NS
Rep /year	4	1227.350	306.838	2.061	NS
Z	3	22285.051	7428.350	49.899	**
Y x Z	3	4.161	1.387	0.009	NS
S	3	21599.180	7199.727	48.364	**
Y x S	3	0.197	0.066	0.000	NS
Z x S	9	197.783	21.976	0.148	NS
YxZxS	9	0.026	0.003	0.000	NS
Error	60	8932.001	148.867		

**Significant at 5% level

Appendix - VI

At 30 DAS 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.09	0.047	0.855875	NS
Z	3	3.918361	1.306	23.85876	**
S	3	5.3508	1.784	32.58084	**
ZxS	9	0.02	0.003	0.049901	NS
Error	30	1.64	0.055		

At 30 DAS 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.12	0.058	0.873843	NS
Z	3	4.333167	1.444	21.65038	**
S	3	5.5692	1.856	27.82614	**
ZxS	9	0.03	0.003	0.045817	NS
Error	30	2.00	0.067		

At 30 DAS pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	0.086	0.086	1.423	NS
Rep /year	4	0.210	0.053	0.866	NS
Z	3	8.246	2.749	45.260	**
Y x Z	3	0.006	0.002	0.032	NS
S	3	10.919	3.640	59.932	**
Y x S	3	0.001	0.000	0.007	NS
Z x S	9	0.052	0.006	0.095	NS
YxZxS	9	0.000	0.000	0.000	NS
Error	60	3.644	0.061		

**Significant at 5% level

Appendix - VII

Analysis of variance for fresh weight at different stages of gobhi sarson

At 60 DAS 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	344.17	172.083	2.639386	NS
Z	3	8390.618	2796.873	42.89804	**
S	3	9948.531	3316.177	50.86306	**
ZxS	9	154.68	17.187	0.263606	NS
Error	30	1955.94	65.198		

At 60 DAS 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	356.21	178.105	2.328782	NS
Z	3	8586.355	2862.118	37.42324	**
S	3	10011.65	3337.217	43.63533	**
ZxS	9	157.09	17.455	0.228226	NS
Error	30	2294.39	76.480		

At 60 DAS pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	13.142	13.142	0.186	NS
Rep /year	4	700.375	175.094	2.472	NS
Z	3	16976.342	5658.781	79.882	**
Y x Z	3	0.632	0.211	0.003	NS
S	3	19959.433	6653.144	93.919	**
Y x S	3	0.750	0.250	0.004	NS
Z x S	9	311.755	34.639	0.489	NS
YxZxS	9	0.017	0.002	0.000	NS
Error	60	4250.336	70.839		

**Significant at 5% level

Appendix -VIII

At 90 DAS 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	2808.85	1404.426	2.161326	NS
Z	3	56635.15	18878.382	29.05266	**
S	3	73054.25	24351.416	37.47532	**
ZxS	9	710.76	78.973	0.121534	NS
Error	30	19493.96	649.799		

At 90 DAS 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	2115.92	1057.958	1.512001	NS
Z	3	56996.33	18998.777	27.15247	**
S	3	71110.08	23703.361	33.87611	**
ZxS	9	690.84	76.760	0.109702	NS
Error	30	20991.22	699.707		

At 90 DAS pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	44.554	44.554	0.066	NS
Rep /year	4	4924.768	1231.192	1.825	NS
Z	3	113575.284	37858.428	56.107	**
Y x Z	3	56.195	18.732	0.028	NS
S	3	144157.313	48052.438	71.215	**
Y x S	3	7.017	2.339	0.003	NS
Z x S	9	1400.828	155.648	0.231	NS
YxZxS	9	0.765	0.085	0.000	NS
Error	60	40485.177	674.753		

**Significant at 5% level

Appendix - IX

At 120 DAS 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	1973.23	986.613	0.526407	NS
Z	3	284242.2	94747.414	50.55246	**
S	3	394014.6	131338.216	70.07547	**
ZxS	9	7613.34	845.927	0.451344	NS
Error	30	56227.19	1874.240		

At 120 DAS 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	1844.57	922.285	0.458309	NS
Z	3	272023.4	90674.473	45.05865	**
S	3	395660.6	131886.872	65.53823	**
ZxS	9	7230.50	803.389	0.399226	NS
Error	30	60370.96	2012.365		

At 120 DAS pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	258.595	258.595	0.133	NS
Rep /year	4	3817.796	954.449	0.491	NS
Z	3	556137.606	185379.202	95.394	**
Y x Z	3	128.054	42.685	0.022	NS
S	3	789670.988	263223.663	135.452	**
Y x S	3	4.278	1.426	0.001	NS
Z x S	9	14839.688	1648.854	0.848	NS
YxZxS	9	4.159	0.462	0.000	NS
Error	60	116598.148	1943.302		

**Significant at 5% level

Appendix - X

At harvest 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	1093.17	546.584	0.793375	NS
Z	3	61702.42	20567.475	29.85402	**
S	3	79809.63	26603.210	38.61499	**
ZxS	9	706.44	78.493	0.113934	NS
Error	30	20668.05	688.935		

At harvest 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	1001.10	500.552	0.659732	NS
Z	3	60743.56	20247.855	26.68683	**
S	3	79641.17	26547.058	34.98923	**
ZxS	9	686.94	76.327	0.100599	NS
Error	30	22761.63	758.721		

At harvest pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	91.260	91.260	0.126	NS
Rep /year	4	2094.272	523.568	0.723	NS
Z	3	122442.573	40814.191	56.387	**
Y x Z	3	3.415	1.138	0.002	NS
S	3	159450.217	53150.072	73.429	**
Y x S	3	0.587	0.196	0.000	NS
Z x S	9	1393.287	154.810	0.214	NS
YxZxS	9	0.090	0.010	0.000	NS
Error	60	43429.673	723.828		

**Significant at 5% level

Appendix - XI

Analysis of variance for dry weight at different stages of gobhi sarson

At 30 DAS 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.00	0.002	1.136191	NS
Z	3	0.203772	0.068	34.59187	**
S	3	0.2409	0.080	40.89455	**
ZxS	9	0.00	0.000	0.120673	NS
Error	30	0.06	0.002		

At 30 DAS 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.00	0.002	1.136191	NS
Z	3	0.183408	0.061	31.13481	**
S	3	0.2208	0.074	37.48243	**
ZxS	9	0.00	0.000	0.094704	NS
Error	30	0.06	0.002		

At 30 DAS pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	0.007	0.007	3.743	NS
Rep /year	4	0.009	0.002	1.136	NS
Z	3	0.387	0.129	65.665	**
Y x Z	3	0.000	0.000	0.061	NS
S	3	0.461	0.154	78.301	**
Y x S	3	0.000	0.000	0.076	NS
Z x S	9	0.004	0.000	0.214	NS
YxZxS	9	0.000	0.000	0.001	NS
Error	60	0.118	0.002		

**Significant at 5% level

Appendix - XII

Analysis of variance for dry weight at different stages of gobhi sarson

At 60 DAS 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	3.27	1.636	2.15339	NS
Z	3	57.53459	19.178	25.24394	**
S	3	71.5608	23.854	31.3981	**
ZxS	9	0.46	0.051	0.067726	NS
Error	30	22.79	0.760		

At 60 DAS 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	2.12	1.059	1.222034	NS
Z	3	64.72474	21.575	24.89132	**
S	3	73.9833	24.661	28.4519	**
ZxS	9	0.53	0.058	0.067323	NS
Error	30	26.00	0.867		

At 60 DAS pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	0.714	0.714	0.878	NS
Rep /year	4	5.390	1.348	1.657	NS
Z	3	122.142	40.714	50.064	**
Y x Z	3	0.118	0.039	0.048	NS
S	3	145.500	48.500	59.638	**
Y x S	3	0.044	0.015	0.018	NS
Z x S	9	0.987	0.110	0.135	NS
YxZxS	9	0.001	0.000	0.000	NS
Error	60	48.794	0.813		

**Significant at 5% level

Appendix - XIII

At 90 DAS 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	2.99	1.493	0.200365	NS
Z	3	204.119	68.040	9.128074	**
S	3	332.0232	110.674	14.84787	**
ZxS	9	1.16	0.129	0.01728	NS
Error	30	223.62	7.454		

At 90 DAS 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	5.93	2.965	0.335933	NS
Z	3	133.7508	44.584	5.051283	**
S	3	356.4321	118.811	13.46115	**
ZxS	9	0.77	0.086	0.009749	NS
Error	30	264.79	8.826		

At 90 DAS pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	19.984	19.984	2.455	NS
Rep /year	4	8.917	2.229	0.274	NS
Z	3	334.023	111.341	13.678	**
Y x Z	3	3.846	1.282	0.158	NS
S	3	688.186	229.395	28.181	**
Y x S	3	0.269	0.090	0.011	NS
Z x S	9	1.913	0.213	0.026	NS
YxZxS	9	0.020	0.002	0.000	NS
Error	60	488.403	8.140		

**Significant at 5% level

Appendix - XIV

At 120 DAS 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	9.00	4.501	0.504122	NS
Z	3	612.3134	204.104	22.8585	**
S	3	865.4664	288.489	32.30905	**
ZxS	9	4.72	0.524	0.05872	NS
Error	30	267.87	8.929		

At 120 DAS 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	20.56	10.278	0.814399	NS
Z	3	688.5812	229.527	18.18791	**
S	3	916.3857	305.462	24.20504	**
ZxS	9	5.52	0.614	0.048617	NS
Error	30	378.59	12.620		

At 120 DAS pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	4.284	4.284	0.398	NS
Rep /year	4	29.558	7.389	0.686	NS
Z	3	1299.453	433.151	40.202	**
Y x Z	3	1.442	0.481	0.045	NS
S	3	1781.246	593.749	55.107	**
Y x S	3	0.606	0.202	0.019	NS
Z x S	9	10.221	1.136	0.105	NS
YxZxS	9	0.020	0.002	0.000	NS
Error	60	646.464	10.774		

**Significant at 5% level

Appendix - XV

At harvest 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	3.04	1.519	0.121181	NS
Z	3	569.3934	189.798	15.14359	**
S	3	668.4216	222.807	17.77735	**
ZxS	9	2.95	0.328	0.026177	NS
Error	30	376.00	12.533		

At harvest 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	6.12	3.062	0.234622	NS
Z	3	583.1846	194.395	14.89757	**
S	3	678.726	226.242	17.3382	**
ZxS	9	3.04	0.338	0.025913	NS
Error	30	391.46	13.049		

At harvest pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	1.325	1.325	0.104	NS
Rep /year	4	9.161	2.290	0.179	NS
Z	3	1152.423	384.141	30.032	**
Y x Z	3	0.155	0.052	0.004	NS
S	3	1347.077	449.026	35.105	**
Y x S	3	0.070	0.023	0.002	NS
Z x S	9	5.995	0.666	0.052	NS
YxZxS	9	0.001	0.000	0.000	NS
Error	60	767.459	12.791		

**Significant at 5% level

Appendix - XVI

Analysis of variance for number of leaf per plant at different stages of gobhi sarson

At 30 DAS 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.53	0.264	1.823164	NS
Z	3	13.06277	4.354	30.05816	**
S	3	9.6324	3.211	22.16469	**
ZxS	9	0.11	0.013	0.086365	NS
Error	30	4.35	0.145		

At 30 DAS 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.40	0.202	0.967053	NS
Z	3	13.06998	4.357	20.90781	**
S	3	9.7644	3.255	15.61994	**
ZxS	9	0.11	0.012	0.059654	NS
Error	30	6.25	0.208		

At 30 DAS pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.060	0.060	0.340	NS
Rep /year	4	0.931	0.233	1.318	NS
Z	3	26.132	8.711	49.320	**
Y x Z	3	0.000	0.000	0.001	NS
S	3	19.396	6.465	36.606	**
Y x S	3	0.001	0.000	0.002	NS
Z x S	9	0.224	0.025	0.141	NS
YxZxS	9	0.000	0.000	0.000	NS
Error	60	10.597	0.177		

**Significant at 5% level

Appendix - XVII

At 60 DAS 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	1.90	0.951	0.750128	NS
Z	3	55.86771	18.623	14.69578	**
S	3	64.2393	21.413	16.89789	**
ZxS	9	0.20	0.022	0.01765	NS
Error	30	38.02	1.267		

At 60 DAS 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	1.13	0.566	0.418495	NS
Z	3	58.25662	19.419	14.36104	**
S	3	64.6668	21.556	15.94123	**
ZxS	9	0.21	0.023	0.017109	NS
Error	30	40.57	1.352		

At 60 DAS pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.487	0.487	0.372	NS
Rep /year	4	3.033	0.758	0.579	NS
Z	3	114.078	38.026	29.034	**
Y x Z	3	0.046	0.015	0.012	NS
S	3	128.843	42.948	32.792	**
Y x S	3	0.063	0.021	0.016	NS
Z x S	9	0.409	0.045	0.035	NS
YxZxS	9	0.000	0.000	0.000	NS
Error	60	78.582	1.310		

**Significant at 5% level

Appendix - XVIII

At 90 DAS 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	5.95	2.975	0.94341	NS
Z	3	104.4163	34.805	11.03595	**
S	3	155.5305	51.844	16.4383	**
ZxS	9	0.43	0.048	0.015125	NS
Error	30	94.61	3.154		

At 90 DAS 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	3.00	1.500	0.394879	NS
Z	3	116.6517	38.884	10.23293	**
S	3	157.1736	52.391	13.78759	**
ZxS	9	0.47	0.053	0.013819	NS
Error	30	114.00	3.800		

At 90 DAS pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	3.067	3.067	0.882	NS
Rep /year	4	8.952	2.238	0.644	NS
Z	3	220.891	73.630	21.177	**
Y x Z	3	0.177	0.059	0.017	NS
S	3	312.686	104.229	29.978	**
Y x S	3	0.018	0.006	0.002	NS
Z x S	9	0.901	0.100	0.029	NS
YxZxS	9	0.001	0.000	0.000	NS
Error	60	208.611	3.477		

**Significant at 5% level

Appendix - XIX

At 120 DAS 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	17.70	8.850	1.84419	NS
Z	3	266.0696	88.690	18.48149	**
S	3	332.8044	110.935	23.11696	**
ZxS	9	1.59	0.177	0.036787	NS
Error	30	143.97	4.799		

At 120 DAS 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	7.50	3.751	0.707711	NS
Z	3	270.4216	90.141	17.00605	**
S	3	347.7969	115.932	21.87196	**
ZxS	9	1.66	0.185	0.034836	NS
Error	30	159.01	5.300		

At 120 DAS pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	1.654	1.654	0.327	NS
Rep /year	4	25.202	6.301	1.248	NS
Z	3	536.407	178.802	35.409	**
Y x Z	3	0.084	0.028	0.006	NS
S	3	680.510	226.837	44.921	**
Y x S	3	0.092	0.031	0.006	NS
Z x S	9	3.250	0.361	0.072	NS
YxZxS	9	0.001	0.000	0.000	NS
Error	60	302.980	5.050		

**Significant at 5% level

Appendix - XX

Analysis of variance for chlorophyll content at 60 DAS, number of primary branches and secondary branches per plant of gobhi sarson

Chlorophyll content 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.01	0.006	0.491525	NS
Z	3	0.485978	0.162	12.80986	**
S	3	1.0884	0.363	28.68906	**
ZxS	9	0.00	0.000	0.016464	NS
Error	30	0.38	0.013		

Chlorophyll content 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.01	0.007	0.508593	NS
Z	3	0.516421	0.172	13.03387	**
S	3	0.8412	0.280	21.2309	**
ZxS	9	0.00	0.000	0.012633	NS
Error	30	0.40	0.013		

Chlorophyll content pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.02160	0.02160	1.67098	NS
Rep /year	4	0.02587	0.00647	0.50024	NS
Z	3	1.00206	0.33402	25.83979	**
Y x Z	3	0.00034	0.00011	0.00880	NS
S	3	1.92120	0.64040	49.54145	**
Y x S	3	0.00840	0.00280	0.21661	NS

Z x S	9	0.00336	0.00037	0.02892	NS
YxZxS	9	0.00001	0.00000	0.00010	NS
Error	60	0.77559	0.01293		

**Significant at 5% level

Number of primary branches 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.27	0.136	1.351566	NS
Z	3	5.741	1.914	18.97931	**
S	3	8.7768	2.926	29.01543	**
ZxS	9	0.05	0.005	0.05327	NS
Error	30	3.02	0.101		

Number of primary branches 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.22	0.109	1.455604	NS
Z	3	6.180651	2.060	27.52142	**
S	3	10.0641	3.355	44.81378	**
ZxS	9	0.06	0.006	0.086246	NS
Error	30	2.25	0.075		

Number of primary branches pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.094	0.094	1.067	NS
Rep /year	4	0.490	0.123	1.396	NS
Z	3	11.916	3.972	45.216	**
Y x Z	3	0.006	0.002	0.022	NS
S	3	18.819	6.273	71.410	**

Y x S	3	0.022	0.007	0.084	NS
Z x S	9	0.106	0.012	0.134	NS
YxZxS	9	0.000	0.000	0.000	NS
Error	60	5.271	0.088		

**Significant at 5% level

Number of secondary branches 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	5.54	2.769	2.941863	NS
Z	3	48.89075	16.297	17.31407	**
S	3	52.6257	17.542	18.63676	**
ZxS	9	0.24	0.026	0.02776	NS
Error	30	28.24	0.941		

Number of secondary branches 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	5.07	2.533	2.761412	NS
Z	3	50.47895	16.826	18.34412	**
S	3	53.9553	17.985	19.60743	**
ZxS	9	0.25	0.027	0.02974	NS
Error	30	27.52	0.917		

Number of secondary branches pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.265	0.265	0.285	NS
Rep /year	4	10.604	2.651	2.853	*
Z	3	99.302	33.101	35.621	**
Y x Z	3	0.067	0.022	0.024	NS
S	3	106.556	35.519	38.223	**

Y x S	3	0.025	0.008	0.009	NS
Z x S	9	0.480	0.053	0.057	NS
YxZxS	9	0.000	0.000	0.000	NS
Error	60	55.755	0.929		

**Significant at 5% level

Appendix - XXI

Analysis of variance for LAI of gobhi sarson

LAI 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.34	0.171	1.755162	NS
Z	3	4.966649	1.656	16.98867	**
S	3	4.6065	1.535	15.75677	**
ZxS	9	0.01	0.001	0.014885	NS
Error	30	2.92	0.097		

LAI 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.34	0.171	1.755162	NS
Z	3	4.966649	1.656	16.98867	**
S	3	4.6065	1.535	15.75677	**
ZxS	9	0.01	0.001	0.014885	NS
Error	30	2.92	0.097		

LAI pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.1262	0.1262	1.1667	NS
Rep /year	4	0.5541	0.1385	1.2811	NS
Z	3	9.9188	3.3063	30.5772	**
Y x Z	3	0.0026	0.0009	0.0082	NS
S	3	9.9917	3.3306	30.8018	**
Y x S	3	0.0160	0.0053	0.0495	NS
Z x S	9	0.0279	0.0031	0.0287	NS
YxZxS	9	0.0000	0.0000	0.0000	NS
Error	60	6.4877	0.1081		

**Significant at 5% level

Appendix - XXII

Analysis of variance for number of siliqua per plant, seeds per siliqua and test weight of gobhi sarson

Siliqua per plant 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	533.22	266.611	0.533007	NS
Z	3	40879.88	13626.627	27.24227	**
S	3	36041.4	12013.801	24.01792	**
ZxS	9	320.83	35.648	0.071267	NS
Error	30	15006.05	500.202		

Siliqua per plant 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	533.22	266.611	0.533007	NS
Z	3	40879.88	13626.627	27.24227	**
S	3	36041.4	12013.801	24.01792	**
ZxS	9	320.83	35.648	0.071267	NS
Error	30	15006.05	500.202		

Siliqua per plant pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	13.954	13.954	0.027	NS
Rep /year	4	1151.199	287.800	0.565	NS
Z	3	80512.578	26837.526	52.660	**
Y x Z	3	4.853	1.618	0.003	NS
S	3	72150.833	24050.278	47.191	**
Y x S	3	3.352	1.117	0.002	NS

Z x S	9	630.921	70.102	0.138	NS
YxZxS	9	0.075	0.008	0.000	NS
Error	60	30578.417	509.640		

**Significant at 5% level

Seeds per siliqua (2022-23)

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	3.88	1.938	2.955581	NS
Z	3	18.31639	6.105	9.313488	**
S	3	29.9172	9.972	15.21225	**
ZxS	9	0.07	0.007	0.01113	NS
Error	30	19.67	0.656		

Seeds per siliqua (2023-24)

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	4.11	2.054	2.870243	NS
Z	3	18.94096	6.314	8.824227	**
S	3	32.4225	10.808	15.10502	**
ZxS	9	0.07	0.008	0.011219	NS
Error	30	21.46	0.715		

Seeds per siliqua pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.3602	0.3602	0.5254	NS
Rep /year	4	7.9823	1.9956	2.9110	*
Z	3	37.2504	12.4168	18.1129	**
Y x Z	3	0.0070	0.0023	0.0034	NS
S	3	62.3141	20.7714	30.3001	**
Y x S	3	0.0256	0.0085	0.0125	NS

Z x S	9	0.1378	0.0153	0.0223	NS
YxZxS	9	0.0001	0.0000	0.0000	NS
Error	60	41.1312	0.6855		

**Significant at 5% level

Test weight 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.19	0.093	1.399131	NS
Z	3	0.803684	0.268	4.026822	*
S	3	0.8433	0.281	4.225318	*
ZxS	9	0.00	0.000	0.001418	NS
Error	30	2.00	0.067		

Test weight 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.48	0.239	2.839762	NS
Z	3	0.806547	0.269	3.188018	*
S	3	0.7692	0.256	3.040399	*
ZxS	9	0.00	0.000	0.001001	NS
Error	30	2.53	0.084		

Test weight pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.0541	0.0541	0.7179	NS
Rep /year	4	0.6651	0.1663	2.2045	NS
Z	3	1.6102	0.5367	7.1158	**
Y x Z	3	0.0000	0.0000	0.0000	NS

S	3	1.6048	0.5349	7.0921	**
Y x S	3	0.0077	0.0026	0.0338	NS
Z x S	9	0.0016	0.0002	0.0024	NS
YxZxS	9	0.0000	0.0000	0.0000	NS
Error	60	4.5258	0.0754		

**Significant at 5% level

Appendix - XXIII

Analysis of variance for seed, stover, biological and harvest index of gobhi sarson

Seed yield 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	57593.13	28796.564	1.941878	NS
Z	3	2935977.75	978659.249	65.99526	**
S	3	1688722.97	562907.658	37.95932	**
ZxS	9	408087.21	45343.023	3.057678	*
Error	30	444877.05	14829.235		

Seed yield 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	55773.02	27886.511	2.194105	NS
Z	3	2863642.75	954547.584	75.10361	**
S	3	1690847.08	563615.692	44.34517	**
ZxS	9	268064.49	29784.944	2.343473	*
Error	30	381292.30	12709.743		

Seed yield pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	11116.939	11116.939	0.807	NS
Rep /year	4	113366.151	28341.538	2.058	NS
Z	3	#########	1932861.984	140.373	**
Y x Z	3	1034.545	344.848	0.025	NS
S	3	#########	1125412.476	81.732	**
Y x S	3	3332.622	1110.874	0.081	NS

Z x S	9	661037.388	73448.599	5.334	**
YxZxS	9	15114.313	1679.368	0.122	NS
Error	60	826169.352	13769.489		

**Significant at 5% level

Straw yield 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	61594.60	30797.300	0.539512	NS
Z	3	12618625.5	4206208.503	73.68504	**
S	3	14530465.3	4843488.421	84.84902	**
ZxS	9	1246623.45	138513.717	2.426506	*
Error	30	1712508.38	57083.613		

Straw yield 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	71926.33	35963.165	0.59562	NS
Z	3	13124501.4	4374833.800	72.45571	**
S	3	15165723.3	5055241.113	83.72457	**
ZxS	9	1317543.23	146393.692	2.424563	*
Error	30	1811382.65	60379.422		

Straw yield pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	40042.516	40042.516	0.682	NS
Rep /year	4	133520.931	33380.233	0.568	NS
Z	3	25738331.307	8579443.769	146.079	**

Y x Z	3	4795.601	1598.534	0.027	NS
S	3	29684157.106	9894719.035	168.474	**
Y x S	3	12031.496	4010.499	0.068	NS
Z x S	9	2563272.488	284808.054	4.849	**
YxZxS	9	894.192	99.355	0.002	NS
Error	60	3523891.033	58731.517		

**Significant at 5% level

Seed yield 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	83604.75	41802.376	0.313079	NS
Z	3	27727754.3	9242584.774	69.22243	**
S	3	25999151.8	8666383.947	64.90697	**
ZxS	9	2766733.24	307414.805	2.302386	*
Error	30	4005602.50	133520.083		

Biological yield 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	34005.38	17002.688	0.149182	NS
Z	3	28248599.7	9416199.912	82.61792	**
S	3	26960276.4	8986758.805	78.84999	**
ZxS	9	2376358.56	264039.840	2.316691	*
Error	30	3419185.66	113972.855		

Biological yield pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	93356.620	93356.620	0.754	NS
Rep /year	4	117610.127	29402.532	0.238	NS
Z	3	55969761.289	18656587.096	150.765	**

Y x Z	3	6592.769	2197.590	0.018	NS
S	3	52953026.033	17651008.678	142.638	**
Y x S	3	6402.223	2134.074	0.017	NS
Z x S	9	5132696.737	570299.637	4.609	**
YxZxS	9	10395.066	1155.007	0.009	NS
Error	60	7424788.159	123746.469		

**Significant at 5% level

Harvest index 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	8.25	4.125	1.124397	NS
Z	3	7.35085671	2.450	0.667954	NS
S	3	9.46669847	3.156	0.860215	NS
ZxS	9	15.07	1.674	0.45633	NS
Error	30	110.05	3.668		

Seed yield 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	11.94	5.972	1.292801	NS
Z	3	4.99351158	1.665	0.360315	NS
S	3	7.70938357	2.570	0.556283	NS
ZxS	9	15.29	1.699	0.367701	NS
Error	30	138.59	4.620		

Harvest index pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.097	0.097	0.023	NS

Rep /year	4	20.194	5.048	1.218	NS
Z	3	12.212	4.071	0.982	NS
Y x Z	3	0.133	0.044	0.011	NS
S	3	16.255	5.418	1.308	NS
Y x S	3	0.921	0.307	0.074	NS
Z x S	9	28.555	3.173	0.766	NS
YxZxS	9	1.798	0.200	0.048	NS
Error	60	248.638	4.144		

**Significant at 5% level

Appendix - XXIV

Analysis of variance for oil content and oil yield of gobhi sarson

Oil content 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	9.73	4.863	0.998533	NS
Z	3	1.49400492	0.498	0.102255	NS
S	3	124.8204	41.607	8.543141	**
ZxS	9	0.00	0.000	5.95E-05	NS
Error	30	146.11	4.870		

Oil content 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	11.89	5.947	1.073844	NS
Z	3	1.44994776	0.483	0.087266	NS
S	3	134.1921	44.731	8.076406	**
ZxS	9	0.00	0.000	5.41E-05	NS
Error	30	166.15	5.538		

Oil content pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.714	0.714	0.137	NS
Rep /year	4	21.621	5.405	1.039	NS
Z	3	2.941	0.980	0.188	NS
Y x Z	3	0.003	0.001	0.000	NS
S	3	258.917	86.306	16.583	**
Y x S	3	0.095	0.032	0.006	NS
Z x S	9	0.005	0.001	0.000	NS
YxZxS	9	0.000	0.000	0.000	NS
Error	60	312.259	5.204		

**Significant at 5% level

Oil yield 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	5610.10	2805.051	0.921065	NS
Z	3	482553.288	160851.096	52.81696	**
S	3	538707.679	179569.226	58.96323	**
ZxS	9	72474.82	8052.758	2.644198	*
Error	30	91363.33	3045.444		

Oil yield 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	8350.23	4175.113	2.051926	NS
Z	3	472635.759	157545.253	77.42813	**
S	3	558366.503	186122.168	91.47271	**
ZxS	9	50028.47	5558.719	2.731921	*
Error	30	61041.87	2034.729		

Oil yield pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	3538.484	3538.484	1.393	NS
Rep /year	4	13960.329	3490.082	1.374	NS
Z	3	955052.723	318350.908	125.331	**
Y x Z	3	136.324	45.441	0.018	NS
S	3	1096468.218	365489.406	143.889	**
Y x S	3	605.963	201.988	0.080	NS
Z x S	9	120297.927	13366.436	5.262	**
YxZxS	9	2205.362	245.040	0.096	NS
Error	60	152405.197	2540.087		

**Significant at 5% level

Protein content 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	1.14	0.570	1.013215	NS
Z	3	39.11482	13.038	23.1685	**
S	3	39.83297	13.278	23.59388	**
ZxS	9	0.08	0.009	0.016415	NS
Error	30	16.88	0.563		

**Significant at 5% level

Protein content 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.62	0.311	0.498859	NS
Z	3	40.19661	13.399	21.51643	**
S	3	38.67656	12.892	20.70278	**
ZxS	9	0.08	0.009	0.014741	NS
Error	30	18.68	0.623		

**Significant at 5% level

Protein content pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	**0.040**	**0.040**	**0.067**	NS
Rep /year	4	**1.762**	**0.440**	**0.743**	NS
Z	3	**79.306**	**26.435**	**44.598**	**
Y x Z	3	**0.005**	**0.002**	**0.003**	NS
S	3	**78.504**	**26.168**	**44.147**	**
Y x S	3	**0.006**	**0.002**	**0.003**	NS
Z x S	9	**0.166**	**0.018**	**0.031**	NS

YxZxS	9	**0.000**	**0.000**	**0.000**	NS
Error	60	**35.565**	**0.593**		

Appendix - XXV

Analysis of variance for pH, EC and CEC in soil after harvest

pH 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.28	0.141	0.485598	NS
Z	3	0.02536274	0.008	0.029133	NS
S	3	0.1008	0.034	0.115785	NS
ZxS	9	0.00	0.000	3.37E-07	NS
Error	30	8.71	0.290		

pH 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.06	0.031	0.08767	NS
Z	3	0.03611577	0.012	0.034184	NS
S	3	0.0849	0.028	0.08036	NS
ZxS	9	0.00	0.000	3.32E-07	NS
Error	30	10.56	0.352		

pH pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.004	0.004	0.012	NS
Rep /year	4	0.344	0.086	0.267	NS
Z	3	0.061	0.020	0.063	NS
Y x Z	3	0.001	0.000	0.001	NS
S	3	0.185	0.062	0.192	NS
Y x S	3	0.000	0.000	0.000	NS
Z x S	9	0.000	0.000	0.000	NS
YxZxS	9	0.000	0.000	0.000	NS
Error	60	19.271	0.321		

**Significant at 5% level

EC 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.07	0.037	1.518497	NS
Z	3	0.017866	0.006	0.247147	NS
S	3	0.0177	0.006	0.24485	NS
ZxS	9	0.00	0.000	6.59E-06	NS
Error	30	0.72	0.024		

EC 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.15	0.073	2.518808	NS
Z	3	0.01054884	0.004	0.120576	NS
S	3	0.0177	0.006	0.202316	NS
ZxS	9	0.00	0.000	3.18E-06	NS
Error	30	0.87	0.029		

EC pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.0024	0.0024	0.0901	NS
Rep /year	4	0.2201	0.0550	2.0662	NS
Z	3	0.0278	0.0093	0.3480	NS
Y x Z	3	0.0006	0.0002	0.0077	NS
S	3	0.0354	0.0118	0.4431	NS
Y x S	3	0.0000	0.0000	0.0000	NS
Z x S	9	0.0000	0.0000	0.0000	NS
YxZxS	9	0.0000	0.0000	0.0000	NS
Error	60	1.5978	0.0266		

**Significant at 5% level

CEC 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	3.67	1.833	0.372758	NS
Z	3	3.22720497	1.076	0.218748	NS
S	3	3.1992	1.066	0.21685	NS
ZxS	9	0.00	0.000	5.19E-06	NS
Error	30	147.53	4.918		

CEC 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	22.33	11.167	1.858457	NS
Z	3	3.15738387	1.052	0.175155	NS
S	3	3.0456	1.015	0.168954	NS
ZxS	9	0.00	0.000	3.95E-06	NS
Error	30	180.26	6.009		

CEC pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.010	0.010	0.002	NS
Rep /year	4	26.000	6.500	1.190	NS
Z	3	6.379	2.126	0.389	NS
Y x Z	3	0.005	0.002	0.000	NS
S	3	6.244	2.081	0.381	NS
Y x S	3	0.001	0.000	0.000	NS
Z x S	9	0.000	0.000	0.000	NS
YxZxS	9	0.000	0.000	0.000	NS
Error	60	327.793	5.463		

**Significant at 5% level

Appendix - XXVI

Analysis of variance for available N, P, K, Zn and S content in soil after harvest

Available N 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	812.11	406.055	1.559431	NS
Z	3	206.485756	68.829	0.264332	NS
S	3	183.8568	61.286	0.235364	NS
ZxS	9	0.02	0.002	8.89E-06	NS
Error	30	7811.60	260.387		

Available N 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	696.10	348.051	1.27747	NS
Z	3	205.911833	68.637	0.251923	NS
S	3	182.6937	60.898	0.223517	NS
ZxS	9	0.02	0.002	8.4E-06	NS
Error	30	8173.59	272.453		

Available N pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	1.084	1.084	0.004	NS
Rep /year	4	1508.212	377.053	1.415	NS
Z	3	412.129	137.376	0.516	NS
Y x Z	3	0.268	0.089	0.000	NS
S	3	366.374	122.125	0.458	NS
Y x S	3	0.177	0.059	0.000	NS
Z x S	9	0.041	0.005	0.000	NS
YxZxS	9	0.000	0.000	0.000	NS
Error	60	15985.197	266.420		

**Significant at 5% level

Available P_2O_5 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	3.83	1.915	0.514981	NS
Z	3	6.31047934	2.103	0.565726	NS
S	3	5.8833	1.961	0.52743	NS
ZxS	9	0.00	0.000	2.45E-05	NS
Error	30	111.55	3.718		

Available P_2O_5 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	4.41	2.204	0.495895	NS
Z	3	2.0434323	0.681	0.153243	NS
S	3	5.9649	1.988	0.447326	NS
ZxS	9	0.00	0.000	6.71E-06	NS
Error	30	133.35	4.445		

Available P_2O_5 pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.073	0.073	0.018	NS
Rep /year	4	8.238	2.059	0.505	NS
Z	3	3.801	1.267	0.310	NS
Y x Z	3	4.552	1.517	0.372	NS
S	3	11.848	3.949	0.968	NS
Y x S	3	0.001	0.000	0.000	NS
Z x S	9	0.000	0.000	0.000	NS
YxZxS	9	0.001	0.000	0.000	NS
Error	60	244.892	4.082		

**Significant at 5% level

Available K_2O 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	690.86	345.432	1.64137	NS
Z	3	429.385358	143.128	0.680095	NS
S	3	426.6588	142.220	0.675777	NS
ZxS	9	0.09	0.010	4.72E-05	NS
Error	30	6313.61	210.454		

Available K_2O 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	1625.27	812.635	3.249292	NS
Z	3	435.692521	145.231	0.580701	NS
S	3	459.4212	153.140	0.612327	NS
ZxS	9	0.10	0.011	4.31E-05	NS
Error	30	7502.88	250.096		

Available K_2O pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	16.138	16.138	0.070	NS
Rep /year	4	2316.134	579.033	2.515	NS
Z	3	863.991	287.997	1.251	NS
Y x Z	3	1.087	0.362	0.002	NS
S	3	881.660	293.887	1.276	NS
Y x S	3	4.420	1.473	0.006	NS
Z x S	9	0.185	0.021	0.000	NS
YxZxS	9	0.001	0.000	0.000	NS
Error	60	13816.485	230.275		

**Significant at 5% level

Available Zn 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.000	0.000	0.078	NS
Z	3	0.001	0.000	1.235	NS
S	3	0.001	0.000	1.207	NS
ZxS	9	0.000	0.000	0.000	NS
Error	30	0.009	0.000		

Available Zn 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.0002	0.0001	0.1830	NS
Z	3	0.0013	0.0004	0.8819	NS
S	3	0.0013	0.0004	0.8961	NS
ZxS	9	0.0000	0.0000	0.0000	NS
Error	30	0.0148	0.0005		

Available Zn pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.000150	0.000150	0.374137	NS
Rep /year	4	0.000229	0.000057	0.142710	NS
Z	3	0.002430	0.000810	2.019927	NS
Y x Z	3	0.000018	0.000006	0.014999	NS
S	3	0.002436	0.000812	2.025327	NS
Y x S	3	0.000006	0.000002	0.004988	NS
Z x S	9	0.000000	0.000000	0.000088	NS
YxZxS	9	0.000000	0.000000	0.000001	NS
Error	60	0.024055	0.000401		

**Significant at 5% level

Available S 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.50	0.248	0.976798	NS
Z	3	0.76935672	0.256	1.009513	NS
S	3	1.5945	0.531	2.092226	NS
ZxS	9	0.00	0.000	0.000184	NS
Error	30	7.62	0.254		

Available S 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.39	0.195	0.953481	NS
Z	3	0.89969788	0.300	1.465952	NS
S	3	1.7217	0.574	2.805309	NS
ZxS	9	0.00	0.000	0.000285	NS
Error	30	6.14	0.205		

Available S pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.06000	0.06000	0.26166	NS
Rep /year	4	0.88640	0.22160	0.96640	NS
Z	3	1.66239	0.55413	2.41655	NS
Y x Z	3	0.00667	0.00222	0.00970	NS
S	3	3.31020	1.10340	4.81191	**
Y x S	3	0.00600	0.00200	0.00872	NS
Z x S	9	0.00094	0.00010	0.00046	NS
YxZxS	9	0.00001	0.00000	0.00000	NS
Error	60	13.75836	0.22931		

**Significant at 5% level

Appendix - XXVII

Analysis of variance for nitrogen content and uptake by seed and stover of gobhi sarson

N content in seed 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.00005	0.00003	0.10526	NS
Z	3	0.04182	0.01394	53.76839	**
S	3	0.04566	0.01522	58.70362	**
ZxS	9	0.00010	0.00001	0.04146	NS
Error	30	0.00778	0.00026		

N content in seed 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.00036	0.00018	0.41478	NS
Z	3	0.04332	0.01444	33.34451	**
S	3	0.04035	0.01345	31.05786	**
ZxS	9	0.00009	0.00001	0.02251	NS
Error	30	0.01299	0.00043		

N content in seed pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.00022	0.00022	0.62397	NS
Rep /year	4	0.00041	0.00010	0.29888	NS
Z	3	0.08510	0.02837	81.94727	**
Y x Z	3	0.00004	0.00001	0.03734	NS
S	3	0.08560	0.02853	82.42696	**
Y x S	3	0.00041	0.00014	0.39287	NS
Z x S	9	0.00018	0.00002	0.05893	NS
YxZxS	9	0.00000	0.00000	0.00028	NS
Error	60	0.02077	0.00035		

**Significant at 5% level

N content in straw 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.00010	0.00005	0.17918	NS
Z	3	0.04523	0.01508	52.26742	**
S	3	0.04506	0.01502	52.06418	**
ZxS	9	0.00013	0.00001	0.05164	NS
Error	30	0.00865	0.00029		

N content in straw 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.00014	0.00007	0.13964	NS
Z	3	0.04489	0.01496	29.24059	**
S	3	0.04273	0.01424	27.83656	**
ZxS	9	0.00012	0.00001	0.02713	NS
Error	30	0.01535	0.00051		

N content in straw pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.00018	0.00018	0.45365	NS
Rep /year	4	0.00025	0.00006	0.15389	NS
Z	3	0.09011	0.03004	75.07377	**
Y x Z	3	0.00001	0.00000	0.01027	NS
S	3	0.08777	0.02926	73.12802	**
Y x S	3	0.00002	0.00001	0.01375	NS
Z x S	9	0.00026	0.00003	0.07191	NS
YxZxS	9	0.00000	0.00000	0.00003	NS
Error	60	0.02401	0.00040		

**Significant at 5% level

N uptake in seed 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	41.30	20.648	0.8775521	NS
Z	3	5677.95771	1892.653	80.440189	**
S	3	3951.42906	1317.143	55.980287	**
ZxS	9	600.08	66.675	2.8337925	*
Error	30	705.86	23.529		

N uptake in seed 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	21.28	10.639	0.649189	NS
Z	3	5647.65739	1882.552	114.8709	**
S	3	3932.35536	1310.785	79.98239	**
ZxS	9	422.79	46.977	2.86646	*
Error	30	491.65	16.388		

N uptake in seed pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	15.947	15.947	0.799	NS
Rep /year	4	62.574	15.643	0.784	NS
Z	3	11324.846	3774.949	189.139	**
Y x Z	3	0.770	0.257	0.013	NS
S	3	7880.214	2626.738	131.610	**
Y x S	3	3.570	1.190	0.060	NS
Z x S	9	1008.730	112.081	5.616	**
YxZxS	9	14.140	1.571	0.079	NS
Error	60	1197.513	19.959		

**Significant at 5% level

N uptake in straw 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	9.08	4.541	1.1068369	NS
Z	3	1119.64606	373.215	90.970633	**
S	3	1283.29964	427.767	104.2674	**
ZxS	9	89.93	9.992	2.4354838	*
Error	30	123.08	4.103		

N uptake in straw 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	9.95	4.974	1.102825	NS
Z	3	1173.67698	391.226	86.7458	**
S	3	1266.53233	422.177	93.60868	**
ZxS	9	91.93	10.214	2.264712	*
Error	30	135.30	4.510		

N uptake in straw pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	4.203	4.203	0.976	NS
Rep /year	4	19.029	4.757	1.105	NS
Z	3	2292.912	764.304	177.485	**
Y x Z	3	0.411	0.137	0.032	NS
S	3	2547.387	849.129	197.183	**
Y x S	3	2.445	0.815	0.189	NS
Z x S	9	181.787	20.199	4.690	**
YxZxS	9	0.064	0.007	0.002	NS
Error	60	258.378	4.306		

**Significant at 5% level

Appendix - XXVIII

Analysis of variance for phosphorus content and uptake by seed and stover of gobhi sarson

P content in seed 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.00001	0.00000	0.11778	NS
Z	3	0.00859	0.00286	75.10509	**
S	3	0.00838	0.00279	73.33941	**
ZxS	9	0.00004	0.00000	0.12607	NS
Error	30	0.00114	0.00004		

P content in seed 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.0000	0.0000	0.4805	NS
Z	3	0.0080	0.0027	60.1048	**
S	3	0.0083	0.0028	62.6317	**
ZxS	9	0.0000	0.0000	0.0977	NS
Error	30	0.0013	0.0000		

P content in seed pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.00012	0.00012	2.95013	NS
Rep /year	4	0.00005	0.00001	0.31266	NS
Z	3	0.01655	0.00552	133.96115	**
Y x Z	3	0.00002	0.00001	0.12912	NS
S	3	0.01670	0.00557	135.13544	**
Y x S	3	0.00000	0.00000	0.03642	NS
Z x S	9	0.00008	0.00001	0.22129	NS
YxZxS	9	0.00000	0.00000	0.00035	NS
Error	60	0.00247	0.00004		

**Significant at 5% level

P content in straw 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.00066	0.00033	0.59259	NS
Z	3	0.09753	0.03251	58.36035	**
S	3	0.09368	0.03123	56.05713	**
ZxS	9	0.00048	0.00005	0.09543	NS
Error	30	0.01671	0.00056		

P content in straw 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.00006	0.00003	0.15474	NS
Z	3	0.09191	0.03064	147.34791	**
S	3	0.09524	0.03175	152.69420	**
ZxS	9	0.00045	0.00005	0.24284	NS
Error	30	0.00624	0.00021		

P content in straw pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.00018	0.00018	0.47452	NS
Rep /year	4	0.00072	0.00018	0.47358	NS
Z	3	0.18939	0.06313	165.04694	**
Y x Z	3	0.00005	0.00002	0.04704	NS
S	3	0.18892	0.06297	164.64186	**
Y x S	3	0.00000	0.00000	0.00392	NS
Z x S	9	0.00093	0.00010	0.27093	NS
YxZxS	9	0.00000	0.00000	0.00006	NS
Error	60	0.02295	0.00038		

**Significant at 5% level

P uptake in seed 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.12	0.061	0.0919822	NS
Z	3	195.613971	65.205	97.759992	**
S	3	137.808773	45.936	68.87128	**
ZxS	9	19.82	2.202	3.3017904	**
Error	30	20.01	0.667		

P uptake in seed 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.12	0.061	0.114746	NS
Z	3	193.117458	64.372	120.3975	**
S	3	135.707046	45.236	84.60542	**
ZxS	9	14.05	1.562	2.920576	*
Error	30	16.04	0.535		

P uptake in seed pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.751	0.751	1.250	NS
Rep /year	4	0.245	0.061	0.102	NS
Z	3	388.707	129.569	215.651	**
Y x Z	3	0.024	0.008	0.013	NS
S	3	273.414	91.138	151.687	**
Y x S	3	0.102	0.034	0.057	NS
Z x S	9	33.427	3.714	6.182	**
YxZxS	9	0.447	0.050	0.083	NS
Error	60	36.050	0.601		

**Significant at 5% level

P uptake in straw 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.13	0.064	0.136957	NS
Z	3	131.527521	43.843	93.956945	**
S	3	140.991392	46.997	100.71748	**
ZxS	9	10.06	1.118	2.3962833	*
Error	30	14.00	0.467		

P uptake in straw 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.49	0.245	0.633513	NS
Z	3	133.021292	44.340	114.6946	**
S	3	146.74448	48.915	126.5271	**
ZxS	9	10.47	1.163	3.009449	*
Error	30	11.60	0.387		

P uptake in straw pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	0.933	0.933	2.186	NS
Rep /year	4	0.618	0.154	0.362	NS
Z	3	264.526	88.175	206.689	**
Y x Z	3	0.023	0.008	0.018	NS
S	3	287.662	95.887	224.766	**
Y x S	3	0.074	0.025	0.058	NS
Z x S	9	20.530	2.281	5.347	**
YxZxS	9	0.004	0.000	0.001	NS
Error	60	25.597	0.427		

**Significant at 5% level

Appendix - XXIX

Analysis of variance for potassium content and uptake by seed and stover of gobhi sarson

K content in seed 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.00010	0.00005	2.85897	NS
Z	3	0.06041	0.02014	1121.01631	**
S	3	0.06102	0.02034	1132.35758	**
ZxS	9	0.00348	0.00039	21.54114	**
Error	30	0.00054	0.00002		

K content in seed 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.00009	0.00004	1.18364	NS
Z	3	0.05925	0.01975	534.74995	**
S	3	0.06236	0.02079	562.78648	**
ZxS	9	0.00332	0.00037	9.99049	**
Error	30	0.00111	0.00004		

K content in seed pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.00034	0.00034	12.29544	**
Rep /year	4	0.00019	0.00005	1.73180	NS
Z	3	0.11963	0.03988	1452.74561	**
Y x Z	3	0.00003	0.00001	0.40217	NS
S	3	0.12338	0.04113	1498.24095	**
Y x S	3	0.00000	0.00000	0.05465	NS
Z x S	9	0.00680	0.00076	27.52859	**
YxZxS	9	0.00000	0.00000	0.01104	NS
Error	60	0.00165	0.00003		

**Significant at 5% level

K content in straw 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.0006	0.0003	0.4599	NS
Z	3	0.0898	0.0299	44.3839	**
S	3	0.0939	0.0313	46.3932	**
ZxS	9	0.0002	0.0000	0.0393	NS
Error	30	0.0202	0.0007		

K content in straw   2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.0011	0.0005	0.5515	NS
Z	3	0.0966	0.0322	33.1576	**
S	3	0.0994	0.0331	34.1075	**
ZxS	9	0.0003	0.0000	0.0307	NS
Error	30	0.0291	0.0010		

K content in straw pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	0.00079	0.00079	0.96418	NS
Rep /year	4	0.00169	0.00042	0.51399	NS
Z	3	0.18637	0.06212	75.48789	**
Y x Z	3	0.00007	0.00002	0.02942	NS
S	3	0.19324	0.06441	78.26906	**
Y x S	3	0.00004	0.00001	0.01640	NS
Z x S	9	0.00051	0.00006	0.06837	NS
YxZxS	9	0.00000	0.00000	0.00006	NS
Error	60	0.04938	0.00082		

**Significant at 5% level

K uptake in seed 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	1.13	0.567	0.8093745	NS
Z	3	305.295442	101.765	145.35123	**
S	3	221.231049	73.744	105.32815	**
ZxS	9	30.73	3.415	4.8776035	**
Error	30	21.00	0.700		

K uptake in seed 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	1.99	0.995	0.988182	NS
Z	3	296.943686	98.981	98.27085	**
S	3	224.011814	74.671	74.1347	**
ZxS	9	22.63	2.515	2.496718	*
Error	30	30.22	1.007		

K uptake in seed pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	0.873	0.873	1.022	NS
Rep /year	4	3.124	0.781	0.915	NS
Z	3	602.176	200.725	235.129	**
Y x Z	3	0.063	0.021	0.025	NS
S	3	445.131	148.377	173.809	**
Y x S	3	0.112	0.037	0.044	NS
Z x S	9	52.798	5.866	6.872	**
YxZxS	9	0.569	0.063	0.074	NS
Error	60	51.221	0.854		

**Significant at 5% level

K uptake in straw 2022-23

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	5.40	2.698	0.8514505	NS
Z	3	0.13	0.065	0.1974842	NS
S	3	334.760782	111.587	338.59535	**
ZxS	9	353.981456	117.994	358.03619	**
Error	30	44.36	4.929	14.9552	**

K uptake in straw 2023-24

source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.00	0.001	0.002338	NS
Z	3	341.788238	113.929	293.7152	**
S	3	372.518231	124.173	320.123	**
ZxS	9	45.19	5.021	12.9446	**
Error	30	11.64	0.388		

K uptake in straw pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	1.762	1.762	4.912	*
Rep /year	4	0.132	0.033	0.092	NS
Z	3	676.482	225.494	628.599	**
Y x Z	3	0.067	0.022	0.063	NS
S	3	726.354	242.118	674.941	**
Y x S	3	0.145	0.048	0.135	NS
Z x S	9	89.539	9.949	27.734	**
YxZxS	9	0.009	0.001	0.003	NS
Error	60	21.523	0.359		

**Significant at 5% level

Appendix - XXX

Analysis of variance for zinc content and uptake by seed and stover of gobhi sarson

Zn content in seed 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.00	0.000	2.181E-05	NS
Z	3	260.115609	86.705	72.198487	**
S	3	251.6337	83.878	69.844222	**
ZxS	9	1.16	0.129	0.1075036	NS
Error	30	36.03	1.201		

Zn content in seed 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	4.55	2.275	2.160063	NS
Z	3	259.065507	86.355	82.00791	**
S	3	237.4092	79.136	75.15255	**
ZxS	9	1.08	0.120	0.114221	NS
Error	30	31.59	1.053		

Zn content in seed pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	0.522	0.522	0.463	NS
Rep /year	4	4.549	1.137	1.009	NS
Z	3	519.116	173.039	153.543	**
Y x Z	3	0.065	0.022	0.019	NS
S	3	488.920	162.973	144.612	**
Y x S	3	0.123	0.041	0.036	NS
Z x S	9	2.243	0.249	0.221	NS
YxZxS	9	0.001	0.000	0.000	NS
Error	60	67.618	1.127		

**Significant at 5% level

Zn content in straw 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.12	0.060	0.0694519	NS
Z	3	230.212407	76.737	88.870769	**
S	3	245.3265	81.775	94.705385	**
ZxS	9	1.86	0.207	0.2397962	NS
Error	30	25.90	0.863		

Zn content in straw 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	3.17	1.583	2.070557	NS
Z	3	237.387527	79.129	103.5016	**
S	3	242.4249	80.808	105.6979	**
ZxS	9	1.88	0.209	0.273137	NS
Error	30	22.94	0.765		

Zn content in straw pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	0.406	0.406	0.498	NS
Rep /year	4	3.286	0.821	1.009	NS
Z	3	467.476	155.825	191.432	**
Y x Z	3	0.124	0.041	0.051	NS
S	3	487.706	162.569	199.716	**
Y x S	3	0.046	0.015	0.019	NS
Z x S	9	3.742	0.416	0.511	NS
YxZxS	9	0.001	0.000	0.000	NS
Error	60	48.840	0.814		

**Significant at 5% level

Zn uptake in seed 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	109.36	54.680	1.7197904	NS
Z	3	8642.6965	2880.899	90.610494	**
S	3	6217.5874	2072.529	65.18552	**
ZxS	9	866.48	96.275	3.0280674	*
Error	30	953.83	31.794		

Zn uptake in seed 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	158.97	79.486	2.569002	NS
Z	3	8550.52511	2850.175	92.11827	**
S	3	6086.63608	2028.879	65.5738	**
ZxS	9	627.82	69.758	2.2546	*
Error	30	928.21	30.940		

Zn uptake in seed pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	25.468	25.468	0.812	NS
Rep /year	4	268.331	67.083	2.139	NS
Z	3	17192.961	5730.987	182.705	**
Y x Z	3	0.261	0.087	0.003	NS
S	3	12301.311	4100.437	130.723	**
Y x S	3	2.912	0.971	0.031	NS
Z x S	9	1477.185	164.132	5.233	**
YxZxS	9	17.117	1.902	0.061	NS
Error	60	1882.041	31.367		

**Significant at 5% level

Zn uptake in straw 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	361.74	180.868	1.8698232	NS
Z	3	28495.4853	9498.495	98.195937	**
S	3	31549.1831	10516.394	108.71903	**
ZxS	9	2281.51	253.501	2.6207056	*
Error	30	2901.90	96.730		

Zn uptake in straw 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	579.15	289.577	2.834271	NS
Z	3	29839.7353	9946.578	97.35328	**
S	3	32470.7901	10823.597	105.9372	**
ZxS	9	2398.38	266.486	2.608266	*
Error	30	3065.10	102.170		

Zn uptake in straw pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	76.667	76.667	0.771	NS
Rep /year	4	940.891	235.223	2.365	NS
Z	3	58327.293	19442.431	195.500	**
Y x Z	3	7.928	2.643	0.027	NS
S	3	64007.988	21335.996	214.540	**
Y x S	3	11.985	3.995	0.040	NS
Z x S	9	4678.756	519.862	5.227	**
YxZxS	9	1.129	0.125	0.001	NS
Error	60	5966.999	99.450		

**Significant at 5% level

Appendix - XXXI

Analysis of variance for sulphur content and uptake by seed and stover of gobhi sarson

S content in seed 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.0006	0.0003	0.4599	NS
Z	3	0.0898	0.0299	44.3839	**
S	3	0.0939	0.0313	46.3932	**
ZxS	9	0.0002	0.0000	0.0393	NS
Error	30	0.0202	0.0007		

S content in seed 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.0011	0.0005	0.5515	NS
Z	3	0.0966	0.0322	33.1576	**
S	3	0.0994	0.0331	34.1075	**
ZxS	9	0.0003	0.0000	0.0307	NS
Error	30	0.0291	0.0010		

S content in seed pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	0.00079	0.00079	0.96418	NS
Rep /year	4	0.00169	0.00042	0.51399	NS
Z	3	0.18637	0.06212	75.48789	**
Y x Z	3	0.00007	0.00002	0.02942	NS
S	3	0.19324	0.06441	78.26906	**
Y x S	3	0.00004	0.00001	0.01640	NS
Z x S	9	0.00051	0.00006	0.06837	NS
YxZxS	9	0.00000	0.00000	0.00006	NS
Error	60	0.04938	0.00082		

**Significant at 5% level

S content in straw 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.00005	0.00003	0.13798	NS
Z	3	0.06680	0.02227	117.28505	**
S	3	0.07048	0.02349	123.73782	**
ZxS	9	0.00048	0.00005	0.28158	NS
Error	30	0.00570	0.00019		

S content in straw 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	0.0001	0.0001	0.2387	NS
Z	3	0.0638	0.0213	76.0110	**
S	3	0.0723	0.0241	86.1664	**
ZxS	9	0.0005	0.0001	0.1821	NS
Error	30	0.0084	0.0003		

S content in straw pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	0.00094	0.00094	3.99333	NS
Rep /year	4	0.00019	0.00005	0.19798	NS
Z	3	0.13056	0.04352	185.37089	**
Y x Z	3	0.00002	0.00001	0.02894	NS
S	3	0.14276	0.04759	202.69298	**
Y x S	3	0.00002	0.00001	0.02343	NS
Z x S	9	0.00094	0.00010	0.44458	NS
YxZxS	9	0.00000	0.00000	0.00011	NS
Error	60	0.01409	0.00023		

**Significant at 5% level

S uptake in seed 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	3.51	1.753	0.8629758	NS
Z	3	444.40371	148.135	72.916115	**
S	3	317.391069	105.797	52.076351	**
ZxS	9	46.74	5.193	2.5560577	*
Error	30	60.95	2.032		

S uptake in seed 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	4.32	2.161	1.491991	NS
Z	3	452.006489	150.669	104.0451	**
S	3	327.955017	109.318	75.49029	**
ZxS	9	34.09	3.788	2.615863	*
Error	30	43.44	1.448		

S uptake in seed pooled mean

Sourse	d.f.	SS	MSS	F cal	F tab
Year	1	2.372	2.372	1.363	NS
Rep /year	4	7.828	1.957	1.125	NS
Z	3	896.339	298.780	171.728	**
Y x Z	3	0.071	0.024	0.014	NS
S	3	645.076	215.025	123.589	**
Y x S	3	0.270	0.090	0.052	NS
Z x S	9	79.862	8.874	5.100	**
YxZxS	9	0.966	0.107	0.062	NS
Error	60	104.391	1.740		

**Significant at 5% level

S uptake in straw 2022-23

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	5.40	2.698	0.8514505	NS
Z	3	872.728907	290.910	91.794391	**
S	3	964.91422	321.638	101.49052	**
ZxS	9	69.07	7.674	2.4214489	*
Error	30	95.07	3.169		

S uptake in straw 2023-24

Source	d.f	S.S	M.S.S	F.Cal	F= Tab
R	2	7.65	3.825	1.506583	NS
Z	3	893.903239	297.968	117.3576	**
S	3	1024.43958	341.480	134.4952	**
ZxS	9	73.04	8.116	3.196455	**
Error	30	76.17	2.539		

S uptake in straw pooled mean

Source	d.f.	SS	MSS	F cal	F tab
Year	1	6.691	6.691	2.344	NS
Rep /year	4	13.047	3.262	1.143	NS
Z	3	1766.549	588.850	206.320	**
Y x Z	3	0.084	0.028	0.010	NS
S	3	1988.712	662.904	232.267	**
Y x S	3	0.641	0.214	0.075	NS
Z x S	9	142.069	15.785	5.531	**
YxZxS	9	0.037	0.004	0.001	NS
Error	60	171.244	2.854		

**Significant at 5% level