SULPHUR AND BORON NUTRITION AND THEIR FOLIAR DIAGNOSIS IN SESAME (*Sesamum indicum* L.)

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Thesis submitted in partial fulfilment of the requirement for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2009

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I hereby declare that this thesis entitled "Sulphur and Boron nutrition and their foliar diagnosis in sesame (*Sesamum indicum* L.)" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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ACKNOWLEDGEMENT

"God is our shelter and strength, always ready to help in times of trouble"

(Psalms.46:1)

I bow my head before God Almighty whose Grace was with me in each and every moment of my life, and leading me through the light which enabled me to complete this task successfully.

I am deeply indebted to Dr. Sumam George, Professor, Department of Soil Science and Agricultural Chemistry, Chairman of the Advisory Committee for her invaluable guidance, inspiring support, encouragement and suggestions without which I would not have been able to complete this venture.

I acknowledge the critical comments and valuable suggestions of Dr. K. Harikrishnan Nair, Dean and Head which helped to accomplish this task.

I am very much grateful to the timely support, sincere efforts, valuable suggestions and constant encouragement from the beginning till the end offered by Dr. K.C. Manorama Thampatti, Professor, Dept. of Soil Science and Agricultural Chemistry which played a major role for the successful completion of this task.

With immense gratitude, I acknowledge the suggestions and guidance offered by Dr. Sverup John, Head, ORARS and Dr. M. Indira, Associate Professor, ORARS, Kayamkulam.

The guidance, support and constant encouragement offered throughout the study period by Dr. Thomas George, Associate Professor of the Dept. of Soil Science and Agricultural Chemistry is remembered with immense gratitude.

I remember gratefully, the guidance offered by Dr. Bhaskaran, Professor, Dept. of Agricultural Extension which helped me to achieve this task.

I am also thankful to the help and guidance offered by Dr. Sudharmaidevi, Professor of the Dept. of Soil Science and Agricultural Chemistry especially during the chemical analysis.

I express my gratitude towards all my teachers of the Dept. of Soil Science and Agricultural Chemistry for their timely help and guidance during the study period.

I acknowledge the help and guidance offered by Dr. Roy Stephen Associate Professor and Dr. R.V.Manju, Associate Professor of the Dept. of Plant Physiology and Dr. Sheela and Dr. Geetha Kumari of the Dept. of Agronomy.

I remember with gratitude, the valuable help offered by Dr. Renukadevi and D. Shobhan Kumar, Technical Officer of RRL, Trivandrum for doing the chemical analysis.

I acknowledge all the non-teaching staff of the Department of Soil Science and Agricultural Chemistry for the help rendered during my research work.

I remember the support and love offered by all my colleagues and friends especially Thania, Thankamoni chechi, Smitha, Gopika and Rani.

I am thankful to Sri. C.E. Ajithkumar, Computer Programmer, for his timely help in statistical analysis

I thank KSCSTE, Thriuvananthapuram for offering me the research fellowship to do PhD programme.

I remember with gratitude, the prayers at every stage, support and encouragement in every sense offered by my papa and mummy without which I would not have accomplished this task.

I am also thankful to my Chechi, Kochu and Vivek for their prayers and encouragement through out the period. Swetha mole who always have a helping hand and a prayerful mind and also Akku mole, Rohit and Aaron owes a lot for the successful completion of this task. I also acknowledge the love and care offered by papa and mummy at Mukhathala.

I cannot express in words the love, care, support and prayers, rendered at each and every stage by my husband Mr. Rinosh Thankachan which enabled me to complete this task.

My little son Abel mon who in turn sacrificed some of his privileges as a child cannot be ignored even in a single moment and I owe this success to him.

Finally, I thank all those who had directly and indirectly help me in this venture.

Jeena Mathew

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LIST OF ABBREVIATIONS

%	Per cent
d S	Deci Siemens
^0C	Degree Celsius
B	Boron
Ca	calcium
CD	Critical difference
cmol	Centimole
cm	Centimeter
Cu	Copper
DOI	Day of Incubation
DAS	Days After Sowing
DTPA	Diethylene Triamine Penta Acetic Acid
EC	Electrical Conductivity
et al.	And others
Fe	Iron
Fig.	Figure
FYM	Farmyard manure
g	Gram
ha^{-1}	Per hectare
K	Potassium
KAU	Kerala Agricultural University
kg	Kilogram
Mg	Magnesium
Mn	Manganese
N	Nitrogen
POP	Package of Practices
P	Phosphorus
RDF	Recommended Dose of Fertiliser
S	Sulphur
spp.	Species
viz.	Namely
Zn	Zinc

Dedicated to My
Parents,
Husband
And
Dear
Abel Mon

INTRODUCTION

1. INTRODUCTION

Agriculture, especially crop production is the mainstay of the Indian economy, which supports about 115.5 million farm families. Oil seeds claim a significant place in our national economy and serve as the raw material for more than 85 per cent of the country's vegetable oil requirement. These are the second largest agricultural commodity in India sharing 15 per cent of the gross cropped area and 8-10 per cent of the value of all agricultural products.

India is fifth among the largest vegetable oil economies of the world next to USA, China, Brazil and Argentina harvesting about 25 million tonnes of oilseeds against the world production of 250 million tonnes per annum with a turn over Rs. 80, 000 crores at current prices. India accounts for about 13 per cent of the world's oilseed area, seven per cent of the world oilseeds output and 10 per cent of the world's edible oil seed consumption.

The diverse agro climatic conditions of the country are favourable for growing the major oil seed crops like sesame, sunflower, ground nut, soybean, mustard and rape seed. Our achievement in the production of oil seeds can be visualized from an increase of 5.5 times during the period between 1950 and 2008. This figure is higher than the increase in total food grain production during this period (Hegde and Babu, 2009).

Since 1995, Indian share in world production of oilseeds has been around 10 per cent. Although, India is a major producer of oilseeds the per capita oil consumption in India is only 10.6 kg $annum^{-1}$ which is lower compared to 12.5 kg $annum^{-1}$ in China, 20.8 kg $annum^{-1}$ in Japan, 21.3 kg $annum^{-1}$ in Brazil and 48.0 kg $annum^{-1}$ in USA (Mahale *et al.*, 2008).

In India the productivity of oil seeds is 446 kg ha^{-1} which is far below the world average productivity of 1632 kg ha^{-1}. The main reason for the low yield and productivity of oil seeds is that these energy rich crops are mostly grown under energy starved conditions. Production of a unit quantity of fat or oil requires more energy than the production of carbohydrates. Inspite of this, oil seeds are mostly grown without irrigation and without adequate quantity of fertilisers or organic manures and biofertilisers. The shortage of edible oils has become a chronic problem in India with increasing demographic pressure (Shekawat and Shivay, 2008).

Among the oilseed crops grown in our country sesame (*Sesamum indicum L.*), commonly known as 'Til' is the most important edible seed crop which in turn is the oldest cultivated crop by man. In India, sesame is being cultivated since the Harappan period. There are archeological remnants dating to 5,500 years ago in the Indian subcontinent. Sesame seeds are considered as micro-capsules for health and nutrition. India dominates world production and export of sesame. Sesame is an important oil seed crop in the tropics and is the source of the unique edible, sesame oil with several superior qualities like low saturated fatty acids and high unsaturated fatty acid contents.

Sesame oil is one of the most stable vegetable oils because of the high level of antioxidants (sesamin, sesamolin, and sesamol). The flour that remains after oil extraction is almost 50 per cent protein, has good effective carbohydrates, and contains water-soluble antioxidants (sesaminol glucosides) that provide added shelf-life to many products. India ranks first in area (29%), production (26%) and export (40%) of sesame in the world. Sesame seeds have a prominent role in health care being the component of bio-medicine. Sesame oil has excellent nutritional, medicinal, cosmetic and cooking qualities for which it is known as 'the queen of oils'. Due to the presence of potent antioxidants, sesame seeds are called as 'the seeds of immortality'. With the growing health consciousness, the international demand and export of sesame are continuously increasing. Consequently, sesame has recently emerged as a valuable export crop, presently earning over Rs. 1000/- crores of valuable foreign exchange from the export of 2.5 lakh tonnes of sesame seed (Duhoon et al., 2004).

In Kerala, sesame, known as the 'queen of oilseeds' and 'poor man's substitute for ghee' occupies a prominent position in state crop map as well as the state economy, being a choice crop of the marginal, small and medium farmers alike. The relative low water requirement and short duration (less than three months) make this an ideal choice in the sandy loam belts of Onattukara region of Kerala, considered as home tract for the crop, where the farmers raise this as a third crop (summer) in the rice fallows after two crops of paddy.

As with other crops, poor nutrient management is one of the major reasons accounting for the low yield and poor quality in oil seed crops. Apart from the primary nutrients, S and B play important roles in the production phenology of oilseed crops. For optimum plant growth and yield, all the secondary and micronutrients are required in appropriate quantities.

Sulphur is a master nutrient in oil production ranked as the fourth major nutrient next to N, P and K. It is required for the synthesis of S containing amino acids and proteins, activity of proteolytic enzymes and increased oil content in oil seeds and is responsible for the formation of chlorophyll, biotin and thiamine and for the metabolism of carbohydrates, proteins and fats. The amino acids containing sulphur are cystene (27%S), cystine (26%S) and methionine (21%S). It increases the oil and the grain protein content in oilseeds. About 90 per cent of plant sulphur is present in these amino acids. Specifically with reference to quality, S improves oil content in seeds, protein content, cereal quality for milling and baking, marketability of copra, quality of tobacco and forages. Sulphur can be regarded as key component of balanced nutrition for higher yields and superior quality of the produce.

Among the seven micronutrients essential for crop growth and development, B plays a vital role in oilseed production. It is needed for carbohydrate transport as well as cellular differentiation and development. This element is directly involved in the process of fertilization contributing to pollen producing capacity of anther, viability of pollen tubes, pollen germination and pollen tube growth. It is also involved in stabilizing cell wall constituents and plasma membrane, enhancement of cell division and tissue differentiation, metabolism of nucleic acid, carbohydrates, protein, auxin and phenols, fertilization and nitrogen metabolism. The translocation of carbohydrates from source to sink is associated with yield enhancement in oil seeds. Boron is also involved in oil synthesis and hence this element can be short listed as a vital element in the growth and productivity of oil seeds. Seed development is hindered by the short supply of B due to the phenol accumulation (Lee and Arnoff, 1967). At low B concentration, the growing points will become necrotic due to the accumulation of phenols and auxins in these regions (Krupnikova and Smrinov, 1981). Agarwala *et al.* (1981) established a close relationship between the boron supply and the pollen producing capacity of the anthers as well as viability of the pollen grains. The primary role of B is in cell wall biosynthesis, phenol metabolism and plasma membrane integrity (Marschner, 1995). According to Shelp *et al.*, (1995), B is essential for the normal growth of monocots, dicots, conifers, ferns and several diatom species.

Intensive cropping along with increased use of S free N and P fertilisers has aggravated the deficiency of sulphur under Indian soil condition. The deficiency of secondary and micronutrients is widespread in the country attributed to the cultivation of high yielding crop varieties, leaching and erosion losses, intensive agriculture, limited recycling of plant residues and gap between removal and supplementation of secondary and micronutrients and increased use of S free fertilisers (Sakal *et al.*, 2001 and Singh *et al.*, 2005).

The total S content in Indian soils ranges from 19 to 9750 ppm (Tandon and Messic, 2002). On the basis of a study conducted by the Sulphur Institute, Washington, 30-35 per cent of the cropped soils are found to be deficient and 35 per cent of the areas are potentially deficient in sulphur.

In Kerala, sesame is cultivated in an area of 732 ha with a production of 294 tonnes confined mainly to the sandy loam tract of Onattukara region stretching over the taluks of Karunagapally, Karthikapally and Mavelikkara (Farm Information Bureau, 2009). The soils are coarse textured, low in cation exchange capacity and major plant nutrients. They have poor organic matter content and low water holding capacity. According to Shekawat *et al.* (2006), the major reasons for S deficiency are coarse texture, low organic matter content, low cycling of crop residues, intensive cropping with high yielding varieties of crops, increased use of straight fertilisers etc which are all applicable to Onattukara soils. At present the fertilisers recommendation of Kerala Agricultural University (KAU, 2008) includes only NPK fertilisers at the rate of 30:15:30 kg ha^{-1}. Hence it was felt appropriate to study the roles of S and B in the nutrition and production phenology of sesame so as to seek the possibility of including these nutrients in the fertilizer schedule for these crops with the aim of increasing its productivity and popularization.

Plant tissue analysis is used to confirm the diagnosis of nutrient deficiency. The mineral composition of the plant is a net result of many complex and interrelated processes, which operate simultaneously. Various soil, fertilizer, plant and climatic factors are associated with the plant nutrient composition. Plant type, plant parts, stage of the crop, age, soil characteristics, soil reaction , soil temperature, soil moisture, soil fertiliser interaction, type and nature of fertiliser reaction and climatic conditions largely change the mineral composition of plants. Leaf analysis provides a snapshot of crop nutritional status at the time of sampling while soil testing provides predictive information about the soil's ability to continue to supply nutrients. Foliar analysis can reveal deficiencies before growth and yields are adversely affected, thereby permitting timely supplemental fertilizer applications to stimulate growth.

Hence the present study was undertaken with the following objectives

i) To understand the nutritional influence of S and B on the growth, yield and quality attributes of sesame.

ii) To standardize the crop growth stage and index tissue for foliar diagnosis of these nutrients.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The present study is a detailed investigation on the nutritional roles of S and B, two essential elements on the growth and yield of sesame, a popular crop in every homestead of Onattukara region of Kerala. The literature pertaining to these two elements in relation to different aspects of the crop relevant to the study with special reference to their foliar diagnosis are reviewed in this chapter.

2.1. SULPHUR

Sulphur is vital element for sustaining life. Oilseed crops have relatively higher S requirement owing to their high content of S containing amino acids and essential oils (Krishnamoorthy, 1989). He reported the involvement of S in various enzymatic processes and bio synthesis of oil in plants. It is essential for the growth and development of plants besides stimulating seed formation and increasing the oil content in oil seed crops. S is regarded as a quality nutrient for oil seed crops as it improves the yield as well as crop quality owing to its influence on protein metabolism and oil synthesis. It is also regarded as the master nutrient for oilseed production (Ram *et al.*, 1998; Legha and Giri, 1999; Misra *et al.*, 1999; Singh, 1999). Substantial requirement of S by oilseeds was reported by Singh (2001); Kumawat and Khangarot (2002); Singh *et al.* (2002); Budhar *et al.* (2003) and Gupta and Abraham (2003). It is required in amounts one-third as that of nitrogen and almost the same as that of phosphorus (Gupta *et al.*, 2004).

2.1.1 Effect of sulphur on growth characters

2.1.1.1 Biometric characters

Sulphur, the fourth major nutrient in crop nutrition has a favorable effect on enhancing the growth characters of crops particularly that of oil seeds which is reflected in attributes like height, number of primary and secondary branches plant^{-1}, internodal length, dry matter production, leaf area index, and finally the harvest index.

Singh and Singh (1995) reported that S applied @ 30 kg ha^{-1} in soybean significantly increased the leaf area plant^{-1} over control.

Timely application of S increases the plant growth by increasing the assimilating surface area. Increasing levels of S upto 40 kg ha^{-1} increased the plant height, number of branches plant^{-1} and number of capitula plant^{-1} in safflower (Abbas *et al.*, 1995). Similar result was reported in lentil (Singh and Kumar, 1996) and mustard (Chauhan *et al.*,1996).

Significant response to S by sunflower on plant growth characters like increased leaf area and plant height was recorded by the application of S at 45 kg ha^{-1}. The number of days to fifty per cent flowering was significantly reduced by the application of S while significant increase was noticed for parameters like leaf area and plant height (Krishnamurthi and Mathan, 1996).

Subramaniyan *et al.* (1999) conducted field experiments to study the response of sesame to S application and found significant response with regard to its biometric characters like height and number of branches plant^{-1} by the application of S. The positive influence of S on stimulating the growth characters like number of branches plant^{-1} and harvest index was also reported in crops such as mustard (Singh, 1999), lentil (Singh *et al.*, 1999) and toria (Sarmah and Debnath 1999).

Sulphur can favourably enhance the chlorophyll synthesis and increase the photosynthetic activity of plants which in turn are evidenced in the growth characters of the plant. Chaubey *et al.* (2000) found that plant height and primary branches plant^{-1} in groundnut were significantly influenced by the application of S @ 45 kg ha^{-1}.

Kumar *et al.* (2001) also studied the underlying effect of S application on growth characters of mustard and got a positive response for characters like plant height, number of primary and secondary branches and harvest index.

Application of S as gypsum @500 kg ha^{-1} significantly increased the plant height of groundnut (Geethalakshmi and Lourdraj, 1998; Dayanand and Meena, 2002; Chauhan *et al.*, 2002).

Application of S provides better nutritional environment for plant growth at active vegetative stages as a result of cell multiplication, elongation and cell expression in the plant body which ultimately increases the plant height. Such a positive response on plant height and leaf area index of sesame grown in sandy loam soil was reported by Sharma and Gupta (2003) and Saren *et al.* (2004). Thakur and Patel (2004) also found that S applied @60 kg S ha^{-1} significantly increased the plant height and recorded maximum leaf area index against control in sesame. Similar results were also recorded by Chettri and Mondal (2004) and Dewal and Pareek (2004).

Singh and Meena (2004) reported that increasing levels of S significantly increased the plant height and number of primary and secondary branches of mustard at harvest up to 60 kg S ha^{-1} over the preceding level of 40 kg S ha^{-1}.

The direct involvement of S in better absorption of applied nutrients culminates in improved growth characters of the plant. Application of gypsum @400 kg ha^{-1} increased the plant height and number of branches $plant^{-1}$ in groundnut and mustard (Mandal *et al.*, 2005; Rana *et al.*, 2005; Dongarkar and Pawar, 2005).

Govahi and Saffari (2006) also noticed the positive correlation between number of primary and secondary branches and dry matter accumulation with increasing levels of S application in spring canola.

Sulphur application @45 kg ha^{-1} increased the number of primary and secondary branches $plant^{-1}$, number of capsule in main stem, primary and secondary branch and number of seeds per capsules in sesame variety TMV6. But it has been found that the plant height was superior with the application of 60 kg S ha^{-1}(Raja *et al.*, 2007a). Such a positive response on the growth characters of Indian mustard such as leaf area index along with plant height and number of primary branches at 90 days after sowing was observed by Kumar and Yadav (2007).

Ravi *et al.* (2008) reported that application of S @ 30 kg S ha^{-1} in sunflower registered the maximum plant height and number of leaves.

Gypsum had been found as the superior source of S by several researchers. Sharma and Arora (2008) studied the effect of gypsum and pyrite as different sources of S and confirmed that 25 kg S ha^{-1}as the optimum dose, preferably of ground gypsum, under rainfed condition in reducing the duration of Indian mustard.

The growth characters of rape seed and mustard such as leaf area, leaf area index, fresh weight and dry weight were significantly enhanced by the application of S in rape seed and mustard (Siddiqui *et al.*, 2008).

From the results of pot culture studies in soybean, it has been concluded that dry weight and chlorophyll content of leaves and the activity of soil enzymes such as catalase, urease, phosphatase, and polyphenoloxidase were enhanced by the increasing S levels from 0 to 60 mg kg^{-1}(Zhao *et al.*, 2008).

2.1.1.2 Root characters

Srinivasan *et al.* (2000) reported that gypsum application @ 40 kg S ha^{-1} increased the number of effective nodules $plant^{-1}$ and nodule dry weight in black gram grown in an acidic Alfisols of Tamil Nadu.

Mathew (2003) concluded from field experiments done in laterite soils of Kerala that the root characters of cowpea like root weight and root volume were positively influenced by the application of phosphogypsum.

From the studies on the effect of S on root characters of soybean, Awlad *et al.* (2003) concluded that application of S @ 30 kg ha^{-1} gave the highest number of nodules $plant^{-1}$ at the later stages of growth of soybean. They studied the effect of S and Zn on nodulation and nutrient content of soybean. The levels of S were from 0 to 50 kg S ha^{-1}. The results indicated that the application of S@ 30 kg S ha^{-1} gave the highest number of nodules $plant^{-1}$.

Govahi and Saffari (2006) conducted an experiment involving different levels of S in spring canola and found that increasing the S rate from 0 to 120 kg ha^{-1} increased the root dry weight of the crop.

Zhao *et al.* (2008) conducted pot culture studies to understand the effect of S fertilisation on the root characters of soybean and observed that the number and weight of side roots increased significantly with increase in S levels from 0 to 60 mg kg^{-1}.

2.1.2 Yield and yield attributes

According to Salbach (1973), S deficiency leads to yield reduction of seed crops. Fertilisers containing S are critical for the grain yield as well as oil and protein synthesis in oil seed crops like sesame, groundnut, soybean, rapeseed and mustard since it is involved in various metabolic functions of the plant (Kumar *et al.*, 1981). Tandon (1984) reported that yield of oilseed crops can be increased by the application of S. Saren *et al* (2004) reported that S nutrition plays an important role in improving the growth and productivity of oil seed crops. The positive response of oil seed crops such as soybean, groundnut sunflower and mustard towards different levels of S was reported by Tewatia *et al.* (2006).

2.1.2.1 Sesame

Reddy and Narayanan (1993) observed the remobilization of macronutrients from various parts of the plant to the capsules of sesame cultivars during the reproductive phase. Several researchers have confirmed the significant response of this crop in terms of yield and yield attributes like seed yield $plant^{-1}$, towards different levels of S such as 10 kg ha^{-1} (Nageshwar *et al.*, 1995), 40 kg S ha^{-1} (Nagawani *et al.*, 2001 and Ghosh, 2000), 60 kg ha^{-1} (Sharma and Gupta, 2003).

The favourable effect of S towards the yield and yield attributes had been mainly attributed to the influence on carbohydrate metabolism which leads to increased translocation of photosynthates. Application of 15 kg S ha^{-1} through gypsum gave remarkably higher seed yields with higher benefit: cost ratio in sesame (Duhoon *et al.*, 2004). Such a positive effect with regard to the improved seed and stick yield with 30 kg S $ha^{-1}$was also concluded from the findings of Saren *et al.* (2004).

An increase in number of seeds $capsule^{-1}$ and seed yield was recorded by the application of 20 kg S ha^{-1} in sesame (Thakur and Patel, 2004). However the thousand seed weight was maximum from 10 kg S ha^{-1}. Such an yield increase of 30.4 per cent over control with 50 kg S ha^{-1} in an Entisol was shown by Sarkar and Saha (2005).

Pandian and Annadurai (2005) concluded the application of 40 kg S ha^{-1} as gypsum as the optimum rate to get the economic yield of sesame grown in Typic Ustochrept soils. They also noticed a synergistic interaction between P and S with 100 kg P and 40 kg S beyond which antagonistic relationship between the two nutrients were observed. They found that the seed and stalk yield of sesame were significantly favored by the application of 40 kg S ha^{-1}. Similar result with 15 kg S ha^{-1} was observed by Duhoon *et al.* (2005).

Application of 45 to 60 kg S ha^{1} was found to improve growth, yield and quality in different sesame cultivars grown in sandy clay loam soil which was significantly superior over other treatments of 15 and 30 kg S ha^{-1}. The highest seed yield was obtained with the application of 60 kg S ha^{-1} (Raja *et al.*, 2007a).

According to Raja *et al.* (2007b), the physical optimal rate for sesame cultivation in sandy clay loam soil was 47.27 kg S ha^{-1} and the economic optimal rate was 46.09 kg S ha^{-1}. Their results revealed that 60 kg S ha^{-1} increased the nutrient uptake and yield of sesame and maintained the soil available nutrient status and the optimum level of S be fixed as 48 kg ha^{-1}.

Mahale *et al.* (2008) found that application of 30 kg S ha^{-1} registered highest grain and stalk yield of sesame and was on par with 60 kg S ha^{-1} which were significantly superior over the control in acidic clay loam soil of Dapoli. Application of 60 kg S ha^{-1} recorded highest weight of seed per plant compared to

30 kg S ha^{-1}. It also produced significant effect on the shelling per cent and harvest index.

2.1.2.2 Groundnut

Several research works pertaining to the favourable influence of S on the yield and yield attributes of groundnut had been reported. This was attributed mainly through the involvement of this nutrient in the synthesis of primary metabolites for improving the yield and quality of oil seed crops and for obtaining better yield under balanced fertilization (Bahl *et al.*, 1986; Singh and Choudhary, 1998).

Geethalakshmi and Lourduraj (1998) studied the effect of gypsum application on the yield and yield attributes of groundnut and found a linear increase in yield components like number of matured pods plant^{-1}, shelling out turn, hundred kernel weight, Sound Mature Kernel (SMK) per cent, and test weight with the increase in rate of gypsum application from 200 to 400 kg ha^{-1}.

Singh and Sarkar (1999) while studying the response of oil seeds to the application of indigenous S sources found that the pod and bhusa yield of groundnut increased significantly with graded doses of gypsum application up to 300 kg ha^{-1}. Such a positive result with the application of 45 kg S ha^{-1} on the yield attributes of the crop such as increased kernel yield, hundred grain weight and dry shoot weight was concluded from the field trials conducted in a Typic Torrior soil (Nabi *et al.*, 1999) and in red laterite and loamy soils(Ghosh *et al.*, (2000).

An experiment to evaluate the field performance of different cultivars of groundnut in response to different levels of S application was conducted by Bandhopadyay and Samui (2000) in sandy loam soil of West Bengal. They reported that the yield components like number of pods plant^{-1}, shelling percentage, hundred kernel weight, pod and kernel yield were significantly improved by the application of S @ 30 kg ha^{-1} as gypsum. Similar results were derived from the field investigations conducted by Kumaran (2000) and Chaubey *et al.* (2000).

Dayanand and Meena (2002) under took a study to assess the growth and yield of groundnut in relation to the application of S and found that the yield and number of pods plant^{-1} and hence the B:C ratio were significantly increased by 60 kg S ha^{-1}. Other attributes like number of kernels pod^{-1}, test weight, pod, kernel and biological yield were maximum with S @ 40 kg ha^{-1}. Similar result was also found by Srilatha *et al.* (2004) by the combined application of 500 kg ha^{-1} of gypsum along with P fertilisers.

Singh *et al.* (2005) concluded from the studies conducted to assess the yield and yield attributes of groundnut in response to S application that its pod yield increased significantly with each successive increase in S application up to 40 kg ha^{-1}.

Mandal *et al.* (2005) studied the yield and yield attributes of groundnut in response to gypsum application and found that application of gypsum @ 400 kg ha^{-1} significantly increased the number of pods plant^{-1}, number of kernels pod^{-1}, hundred kernel weight, shelling percentage and pod and haulm yield of groundnut. Similar result was reported by Dutta and Mandal (2006).

Singh and Mann (2007) conducted field study to know the interaction effect of S and Zn in groundnut and found that increasing levels of S application significantly increased the pod yield up to 40 kg S ha^{-1}.

In a field trial to study the effect of different sources and levels of S on the yield of groundnut in a groundnut – rice cropping system, Jena *et al.* (2008) found gypsum as the superior S source. The pod and vine yield were significantly influenced by the application of different levels of S. The highest pod yield was obtained with 60 kg S ha^{-1} applied through gypsum.

2.1.2.3 Soybean

Majumdar *et al.* (2001) reported that application of 40 kg S ha^{-1} increased the number of pods plant^{-1} and hundred seed weight of soybean by 7.6 percent and 2.6 per cent respectively.

Application of S @ 50 kg ha^{-1} significantly increased the seed yield of soybean by 38.72 per cent over control and gypsum was found to be the superior source of S (Singh *et al.*, 2002).

Gupta and Abraham (2003) studied the performance of soybean in response to the application of S and rhizobium and concluded that application of 30 kg S ha^{-1} significantly improved the yield and yield attributing characters like number of pods $plant^{-1}$, total grains $plant^{-1}$, number of grains pod^{-1}, and hundred seed weight. Parameters like number of pods $plant^{-1}$, number of seeds pod^{-1}, grain and stover yield showed an increase of 31.61, 6.57, 23.76 and12.5 per cent respectively over control.

Chaurasiya *et al.* (2009) conducted an investigation to find out the effect of dose and sources of S on yield of soybean and found that the positive effect of S is reflected in the grain and bhusa yield of soybean which was enhanced by the application of S upto 30 kg ha^{-1}.

2.1.2.4 Sunflower

From the results of the field study conducted to understand the effect of S on the yield of sunflower, Agarwal *et al.* (2000) concluded that significant response in terms of silique $plant^{-1}$, and test weight was obtained by the application of S up to 40 kg ha^{-1} in a silt loam soil. This was also noticed in the research findings of Nepalia and Jain (2000). An increase of 29.7 per cent over control was also reported by them. Such a favourable influence of S in sunflower grown in a Typic Albaquept soil with the application up to 80 kg ha^{-1} was concluded from the investigations of Nasreen and Huq (2002).

Budhar *et al.* (2003) while studying the influence of S on the yield and economics of sunflower observed that application of 45 kg S ha^{-1} as gypsum significantly increased its yield and yield attributes like grain yield, number of grains $capitulum^{-1}$ and the test weight. A linear increase in grain yield with graded levels of S was noticed in the crop. Similar results were also reported by Ramu and Reddy (2004) and Poonkodi and Poomurugesan (2005).

Kumar and Singh (2007) conducted experiments to know the influence of S along with P and concluded that the highest seed yield and net returns was obtained by the application of 30 kg S ha^{-1} along with 60 kg P ha^{-1}.

From the experiments conducted to study the effect of S along with N and B on the productivity of sunflower, Shekhawat and Shivay (2008) found that among other nutrients S application was much beneficial in improving the yield attributing characters like capitulum diameter, number of seeds $capitulum^{-1}$ and the seed yield when applied @ 25 kg ha^{-1}.

The growth parameters of sunflower like diameter of head and number of seeds per flower revealed the positive influence of S in enhancing the yield and yield attributing characters. Also the grain and stover yield was significantly influenced by the S application and a linear relationship was recorded by Dhage and Patil (2008).

A linear increase in grain and bhusa yield and test weight of sunflower was observed with increasing rate of S and the highest grain yield was obtained with S @ 60 kg ha^{-1}(Shekawat *et al.*, 2008).

2.1.2.5 Mustard

Dubey *et al.* (1994) while studying the response and economics of S nutrition in Indian mustard found a significant increase in seed yield by the addition of 300 kg S ha^{-1}.

Purakayastha and Nad (1996) studied the effect of S along with Mo and Mg on the yield of mustard and concluded that application at increasing levels from 0 to 90 kg S ha^{-1} to mustard grown in Typic Ustochrept soil increased its seed yield.

Singh and Sarkar (1999) found that the grain yield of mustard increased significantly with the application of graded levels of S up to 60 kg ha^{-1} and that further increase up to 80 kg ha^{-1} decreased the grain yield.

In an experiment to assess the effect of S on the growth and yield of mustard and rape seed, Ahmad *et al.* (1998) reported that the maximum yield in rape seed and mustard was recorded by the treatment which received S @ 40 kg ha^{-1}.

Supply of S helped in floral primordial initiation that evidently results in higher number of seeds per plant and other yield attributing characters. Kumar *et al.* (2001) carried out an investigation to analyse the response of mustard to different levels and source of S and found that application of S @ 40 kg ha^{-1} significantly increased the number of siliqua $plant^{-1}$, seed $siliqua^{-1}$, thousand grain weight and harvest index.

In order to evaluate the superior source of S and to study the response of mustard to different levels of S, an experiment was conducted by Chauhan *et al.* (2002) and found gypsum as the superior source which when applied at 30 kg S ha^{-1} significantly increased the siliqua length, number of siliquae $plant^{-1}$, thousand seed weight and ultimately the seed yield of mustard.

Singh and Meena (2004) conducted field experiments to know the effect of different levels of S on the growth and yield of mustard in a loamy soil and concluded that increasing levels of S increased the seed yield, and dry matter content up to 80 kg S ha^{-1}. However the attributes like siliqua $plant^{-1}$, seed $siliqua^{-1}$ and test weight were maximum with 60 kg S ha^{-1}.

Rana *et al.* (2005) made an investigation to understand the influence of S on the growth and yield of mustard in a deep sandy loam soil and found that significant increase in seed and biological yield and harvest index were obtained with 20 kg S ha^{-1}. The optimum dose for S was worked out as 30.9 kg S ha^{-1} and the response per kg of S in terms of seed yield was found to be 13.3 kg ha^{-1}. The returns on each rupee of investment was found to be 5.63.Similar result was also reported by Jat and Mehra (2007).

The positive response of mustard with increasing levels of applied S in terms of its yield and yield attributes was found by several researchers. S application @ 40 kg S ha^{-1} recorded significantly higher seed and stover yield in mustard which was 28.1 and 37.4% higher than the control (Kumar *et al.*, 2006;

Kumar and Yadav, 2007; Piri and Sharma, 2007; Basumatary and Talukdar, 2007).

Sharma and Arora (2008) reported that the application at 50 kg S ha^{-1} as ground gypsum recorded significantly highest mean seed yield in Indian mustard which was 30 per cent more over control in the first and second year.

2.1.2.6 Safflower

Increasing levels of S significantly enhanced the yield and its attributes in safflower. Abbas *et al.* (1995) conducted field experiments to understand the effect of S fertlisation in safflower and arrived at the conclusion that the increasing the level of S increased its yield and yield attributes like grain and biomass yield, capitula plant^{-1}, and harvest index. Similar result highlighting the positive response with the application up to 45 kg S ha^{-1} was concluded from the studies of Babhulkar *et al.* (2000).

Ravi *et al.* (2008) found that the yield determining components of safflower like number of capsules per plant, seed weight head^{-1}, thousand seed weight and seed yield were significantly and positively influenced by the application of S @ 30 kg ha^{-1}. Significantly superior harvest index was observed for S @ 60 kg ha^{-1}.

2.1.2.7 Lentil

Singh and Kumar (1996) conducted an experiment to study the effect of varying levels of S on lentil and found that its yield and yield attributes like number of pods plant^{-1} and test weight and the harvest index were significantly increased by the application of S @ 30 kg ha^{-1}.

The overall increase in grain yield with increase in levels of S was quite evidenced by the increase in grain yield of lentil to the range of 55.1 per cent.with the application of 60 kg S ha^{-1} over control (Singh *et al.*, 1999).

2.1.2.8 Rapeseed

Sulphur is an indispensible nutrient for the synthesis of certain amino acids and also a constituent of glutathione which plays an important role in respiration and in the synthesis of essential oils and hence plays a significant role in promoting the yield characters of rape seed (Goswami, 1986).

Response to applied S has also been reported by Sreemannarayana and Raju (1994). Paulsen *et al.* (1999) concluded from field trials conducted to understand the influence of S fertilization on the yield and quality of rape seed and found that application of 40 kg S ha^{-1} could satisfy its S demand and increased its yield and yield attributes and there by to an environmentally sustainable production of this crop.

Mishra *et al.* (1999) studied the effect of S on the performance of rape seed grown in a sandy loam soil of Orissa and found that increasing level of S from 0 to 40 kg ha^{-1} significantly increased its seed yield.

Sarangthem *et al.* (2008) evaluated the response of rape seed to the application of different dose of S and found that increasing the level of S from 0 to 40 kg ha^{-1} recorded a positive influence on the seed yield of and the highest value was obtained at 40 kg S ha^{-1}.

The enhancement of yield attributes like pods per plant, seeds pod $^{-1}$, seed yield per $hectare^{-1}$ in rape seed and mustard was also documented by Siddiqui *et al.* (2008).

2.1.2.9 Brassicas

Singh *et al.* (2000a) performed field experiments to evaluate the response of brassicas to different levels of S ranging from 0 to 45 kg ha^{-1} and found that application of 45 kg S ha^{-1} improved the seed yield and its attributes like silique $plant^{-1}$ and seeds $silique^{-1}$. It also showed the highest B:C ratio. The increase in yield was observed to be 23.8 per cent over control.

Bhusa and grain yield of niger crop increased significantly with successive increase in levels of gypsum up to 300 kg ha^{-1}(Singh and Sarkar, 1999).

After conducting field experiments in Bihar plateau, with graded levels of fertiliser S at rates ranging from 0 to 60 kg ha^{-1}, Singh *et al.* (2000b) inferred that the grain and bhusa yield of niger was increased by 43.5 per cent over control with the application of 45 kg S ha^{-1}.

Kumar *et al.* (2002) reported that seed yield and its attributes like siliquae per plant, seeds $siliquae^{-1}$ and thousand seed weight of Brassica species increased significantly with the application of S @25 kg ha^{-1} with an increase of 23.4 per cent over control.

Sarker *et al.* (2002) after studying the effect of S fertilisation on the yield and its attributes of soybean showed that the highest biological yield, effective pods $plant^{-1}$, pod length, seed $plant^{-1}$, hundred seed weight and harvest index were recorded with 30 kg S ha^{-1}.

Malhi *et al.* (2007) conducted a field study to understand the yield and other parameters of brassica oil seed crops in response to S fertilisation and inferred that seed yield was usually maximized at the rate of 30 kg S ha^{-1} for all brassica species.

2.1.2.10 Canola

Jackson (2000) studied the positive influence of S fertlisation in canola and inferred 20 kg S ha^{-1} as the optimum dose for its seed yield.

Govahi and Saffari (2006) studied the interactive effect of S and K on the yield and its components of canola and concluded that average number of seeds pod^{-1} and thousand seed weight increased with increasing levels of S application and recorded 13.5 per cent and 37.59 per cent increase respectively over control. Malhi and Gill (2006) also found the positive influence of S application on the yield of Canola.

Brennen and Bolland (2008) observed that grain yield response to applied S in canola occurred only when nitrogen was also applied along with it and reached a maximum yield plateau when 13 kg S ha^{-1} was applied.

2.1.3 Dry matter accumulation

Several workers have confirmed the favourable influence of S application on improving biomass yield and the dry matter accumulation in oilseed crops.

Experiments conducted to reveal the influence of different levels of S on the growth and yield of soybean found maximum dry matter accumulation at 30 kg S ha^{-1} (Singh and Singh, 1995).

The enhanced synthesis of chlorophyll facilitated by the addition of S enables the plants to capture greater insolation and thereby result in increased dry matter production. Legha and Giri (1999) conducted a field trial to understand the significance of S on the growth characters of sunflower and concluded that significant increase in dry matter production could be obtained by the application of 30 kg S ha^{-1} as gypsum. Similar result in soybean was documented by Awled *et al.* (2003).

In order to understand the effect of gypsum application on the performance of groundnut, Geethalakshmi and Lourdraj (1998) conducted field trials and concluded that the application of gypsum @500 kg ha^{-1} enhanced the dry matter yield in groundnut.

Saren *et al.* 2004 studied the effect of different levels of S on the growth and productivity of summer sesame and reported that the dry matter production was favourably influenced by the increasing levels of S from 0 to 45 kg S ha^{-1}.

Poonkodi and Poomurugesan (2004) while studying the effect of S on the growth and yield of sunflower found that the application of S at increasing rate from 0 to 60 kg ha^{-1} increased the dry matter content and significant response was recorded at 40 kg ha^{-1}. Similar results in mustard was concluded by Singh and Meena (2004).

The increased growth components of the plant due to the application of S attributes itself to the increased chlorophyll synthesis and enhanced photosynthetic activity which finally results in increased dry matter yield. Sarkar and Saha (2005) reported that increase in levels of S and B significantly increased the biomass production in sesame.

Ravi *et al.* (2008) reported that application of S @ 30 kg S ha^{-1} recorded the maximum dry matter production in sunflower. Karthikeyan and Shukla (2008) concluded from field trials that the significant increase in dry matter of sunflower and mustard by the application of S and B @ 60 mg kg^{-1} and 2 mg kg^{-1} respectively.

2.1.4 Oil content

Sulphur is a quality nutrient involved in enhancing the oil and protein content in oilseeds. S is directly involved in the synthesis of oil in oilseed crops. Role of S in the oil content and the quality is well documented. S helps in oil synthesis by enhancing the level of thioglucosides (Singh *et al.*, 1987).

In India, S is most frequently associated with improvement in oil content of oilseed crops. Each kg of S applied can increase the production of edible oil by 3.0-3.5 kg (Tandon, 1988).

The essentiality of S in the formation of amino acids and proteins and the synthesis of oil and chlorophyll was established in several crops such as soybean (Mishra and Agarwal, 1994), sunflower (Gangadhara *et al.*, 1990 and Ramu and Reddy, 2004), mustard (Dubey *et al.*, 1994 and Piri and Sharma, 2007) and groundnut (Mandal *et al.*, 2005 and Singh and Mann, 2007).

Das and Das (1995) conducted a field trials to under stand the effect of S fertilisation on the oil content and quality of toria and found a marked effect of S application on this parameter and was recorded to be 12.5 per cent over control with 45 kg S ha^{-1}. Oil content increased linearly with increasing levels of S application.

Nageswar *et al.* (1995) studied the effect of S on the oil content and quality of sesame seed and found that S application @10 kg ha^{-1} resulted in significantly higher oil content in sesame seed. Similar results with the application of S up to 60 kg ha^{-1} in rape seed and mustard was reported by Ahmad *et al.* (1998).

Singh *et al.* (1999 a) while analysing the response of brassicas to S application observed that for each successive increase in S levels from 0 to 45 kg ha^{-1}, significant increase in the oil content and yield was observed.

Glutathione is an essential compound in oil synthesis. S is a vital constituent of this compound. Each successive increase in S level from 0 to 50 kg ha^{-1} significantly increased the oil content in Indian mustard grown in a Typic Usti Psamment soil (Chauhan *et al.*, 1996). Similar result was also observed by Sarma and Debnath (1999).

The significant influence of S in enhancing the oil content in sunflower was reported by Tamak *et al.* (1997) and Legha and Giri (1999).

The enhancement of oil content in rape seed through the production of glucosinolate was emphasised by Paulsen *et al.* (1999).

Supply of S ensures the availability of enzymes which take part in the synthesis of fatty acids. Singh *et al.* (2000 a) found that each successive increase in S levels from 0 to 45 kg ha^{-1} significantly increased the oil content in brassicas. Similar result in niger with the addition of 15 to 60 kg ha^{-1} was found by Singh *et al.* (2000 b). An increase of 3.7 per cent compared to control was recorded with 60 kg S ha^{-1}.

Bandhopadyay and Samui (2000) while studying the effect of different sources and levels of S in groundnut found that application of 30 kg S ha^{-1} as gypsum significantly improved the oil content in groundnut.

Baphulkar *et al.* (2000) conducted field trials to study the effect of S on yield and quality of safflower and concluded that around 21 per cent increase in the oil content over control was obtained by the application of 60 kg S ha^{-1}.

The positive role of S in ensuring the increased synthesis of oil was also documented in crops such as rapeseed (Fismes *et al.*, 2000), Canola (Jackson, 2000) and sesame (Nagwani *et al.*, 2001).

After studying the response of soybean to different levels of S in a Typic Hapludalf soil, Majumdar *et al.* (2001) concluded that its oil content increased significantly with increasing levels of S and showed an increase of 24.17 per cent over control by the application of 40 kg S ha^{-1}. Similar result in Indian mustard was recorded by Kumar *et al.* (2001).

Improved oil content by the application of 25 to 50 kg S ha^{-1} was reported in brassicas and mustard by Kumar *et al.* (2002) and Chauhan *et al.* (2002) respectively.

Misra *et al.* (2002) studied the effect of different levels of S on the quality characteristics of mustard and reported that with the addition of 50 ppm of S, significant increase in oil content was recorded.

Ahmad and Abdin (2002) found that a balanced N and S supply improved the quantity and quality of oil of Brassica genotypes and reported that application of combined doses of S and N resulted in 5.0–10.9 per cent enhancement in the oil content of seeds of rape seed when compared with application of N without S. Maximum oil content 51.2 per cent was observed in treatment which received 60 kg S ha^{-1}.

Singh *et al.* (2002) reported that maximum oil content of 23.2 percent was registered in the treatment which received 60 kg S ha^{-1} in Soybean.

Poonia (2003) found that oil yield in sesame increased by the application of S up to 50 kg ha^{-1}. Seed protein content was increased by the application up to 25 kg S ha^{-1}.

Enhanced S content in seed due to the application of S promotes the oil yield. Increase in the levels of S from 20 to 80 kg ha^{-1} enhanced the oil yield and protein content Indian mustard (Singh and Meena, 2003).

Sharma (2003) reported that increasing levels of S significantly improved oil content of soybean and recorded an increase of 3.16 per cent over control by the application of 50 kg S ha^{-1}.

Kalaiyarasan *et al.* (2003) reported that the oil and protein content of groundnut kernel significantly increased due to S addition. Application of 45 kg S ha^{-1} recorded the highest oil and protein content. The optimum oil yield in sunflower was obtained with 49.5 kg S ha^{-1} and N @ 107 kg ha^{-1} in a sandy loam soil (Poonia, 2003).

Singh and Pareek (2003) studied the effect of different levels of S on the quality of taramira (*Eruca sativa*), an oil seed crop and found that application of 60 kg S ha^{-1} significantly increased the oil content which was 21.27 per cent over control.

Thakur and Patel (2004) studied the response of sesame to different levels of S and found that the oil content and yield was significantly increased by the application of 20 kg S ha^{-1}.

To evaluate the efficiency of different S sources and to determine the suitable S requirement in sesame Duhoon *et al.* (2005) carried out field experiments and concluded that application of 15 kg S ha^{-1} as gypsum significantly increased the oil content.

Thorat *et al.* (2005) found that application of S @ 50 kg ha^{-1}significantly influenced the protein and oil content in sunflower and this was significantly superior over control.

Field experiment to study the effect of levels of S on Indian mustard was undertaken by Kumar *et al.* (2006) in a sandy loam soil and found that oil production increased significantly with increase in S levels and the maximum content was recorded with S @ 40 kg ha^{-1} attributed to the increase in production of glucosides.

The oil content of crops increased with increase in the rate of S. This response was well documented many several researchers in crops such as mustard (Piri and Sharma, 2006) with 45 kg S ha^{-1}, groundnut (Dutta and Mandal, 2006) with gypsum @ 500 kg ha^{-1}, rapeseed (Farahbakhsh *et al.*, 2006) with 200 kg S ha^{-1}, canola (Govahi and Saffari, 2006) and with 120 kg S ha^{-1}, sunflower (Rana *et al.*,2007). Several workers such as Kumar and Yadav (2007); Piri and Sharma (2007) and Sharma and Arora (2008) reported the essentiality of S in oil formation of Indian mustard.

Ahmad *et al.* (2007) reported that in canola, oil content increased significantly up to 20 kg S ha^{-1} but further increase in S level did not enhance oil content. Similar result in sunflower was reported by Hassan *et al.* (2007).

Oil content in seed increased with S fertilization for all brassica species. There was a significant increase of protein concentration in seed due to S fertilization (Malhi *et al.*, 2007).

Sulphur is involved in the formation of glucosides and glucosinolates and sulphydril linkage and activation of enzymes which aid in biochemical reaction within the plant. Ravi *et al.* (2008) reported that in sunflower, the treatment which received 30 kg S ha^{-1} recorded the maximum oil content of 29.1 per cent which was significantly superior over the lower levels.

Raja *et al.* (2007 a) found that the oil content and yield of sesame was significantly increased with increasing S levels and the maximum was recorded at 60 kg ha^{-1}.

The oil content in canola increased with increasing rate of S application (Brennen and Bolland, 2008).

Dhage and Patil (2008) while studying the effect of S sources and their rates on yield and quality of sunflower observed that the oil content increased with increase in the level of S and the highest content was recorded by 60 kg S ha^{-1}. Increasing levels S from 0 to 40 kg ha^{-1} increased the oil content in rapeseed (Sarangthem *et al.*, 2008) and mustard (Jena *et al.*, 2008).

The positive influence of sulphur in the oil and protein content of soybean was also emphasised by Chaurasiya *et al.* 2009). It has been found that the increasing levels of S significantly increased its protein and oil content upto 30 kg S ha^{-1}.

Field investigation to study the response of groundnut to gypsum along with different levels of fertilisers was conducted by Kumaran (2000) and found that the highest shelling percentage, harvest index, oil yield and protein content were registered with the application of recommended dose of fertiliser along with gypsum @ 400 kg ha^{-1}.

2.1.5 Crop quality

The deficiency of sulphur causes accumulation of nitrates, amides and carbohydrates which retard the formation of proteins (Tandon, 1989) and thus reduces the crop quality of oilseeds. Fismes *et al.* (2000) emphasised the essentiality of S in improving the quality of fatty acids in oil seed rape.

In brassicas, with each successive increase in sulphur levels from 0 to 45 kg ha^{-1} significant increase in the, protein content and iodine value was observed (Singh *et al.*, 1999a).

Baphulkar *et al.* (2000) reported 14.9 per cent increase in the protein content over control by the application of 60 kg S ha^{-1}.

According to Ahmad and Abdin (2000) sulphur application increased the oleic acid (18:1) content, and decreased the erucic acid (22:1) content in rapeseed which led to a reduced 22:1/18:1 ratio and thus, improved the quality of oil. This ratio is closely related to the N: S ratio in the seeds.

Majumdar *et al.* (2001) concluded that the protein content of soybean grown in a Typic Hapludalf soil showed an increase of 11.26 per cent over control by the application of 40 kg S ha^{-1}.

Misra *et al.* (2002) observed that the content of oleic and linoleic acid increased with S addition from 0 to 50 ppm while that of erucic acid content decreased and thereby improved the quality of oil.

A narrow N to S ratio, with both at higher levels, increased the oil content but raised the saponification value of the oil, a measure of free fatty acids. Whereas, a proportionately narrow N to S ratio at moderate dose resulted in adequately higher seed and oil yield with relatively low saponification value, associated with increased iodine value of the oil, indicating respectively low free fatty acids and higher proportion of unsaturated fatty acids, an index for better quality of the oil (Nad *et al.*, 2001).

Dayanand and Meena (2002) found that the protein content of groundnut kernel was significantly enhanced due to the application of S @ 45 kg ha^{-1} which was 25.6 per cent over control.

Ahmad and Abdin (2002) reported that proper balance between N and S in Brassica genotypes resulted in an increase in the unsaturated fatty acids such as oleic acid and linoleic acid content and decreased in eicosenoic acid and erucic acid contents.

The improvement in quality in terms of protein content by the application of 50 kg ha^{-1} with an increase of 11.23 per cent over control was recorded in soybean (Sharma, 2003) and sesame Poonia (2003).

Singh and Pareek (2003) reported significant increase in protein content of taramira with 40 kg S ha^{-1} which was found to be 12.51 per cent over control.

Govahi and Saffari (2006) reported that significant increase in protein content (32.8%) of spring canola was obtained with 120 kg S ha^{-1}.

Ahmad *et al.* (2007) found that in canola glucosinolate content increased from 13.6 to 24.6 μ mol g^{-1} as S rate was increased from 0 to 30 kg ha^{-1}. Protein content also significantly increased with increase in the rate of application of S. Similar result in rape seed was reported by Basumatary and Talukdar (2007).

Siddiqui *et al.* (2008) found that the fatty acid composition of rape seed and mustard were significantly influenced by the application of S such that there was an increase of Stearic acid, linoleic acid, linolenic acid and erucic acid.

Ravi *et al.*, (2008) reported that in sunflower the treatment which received 30 kg S ha^{-1} recorded maximum increase in protein content of 29.1 per cent over control and was significantly superior over the lower levels. The lowest saponification value, acid value and that of iodine number was recorded by the treatment which received 30 kg S ha^{-1}.

Shekawat and Shivay (2008) reported that the application of sulphur and boron significantly reduced the saponification value and acid value by improving the oil quality but increased the iodine number. Sulphur application significantly reduced the content of saturated fatty acids such as palmatic and stearic acid in sunflower.

Raja *et al.* (2007a) found that the quality parameters of sesame such as crude protein content was increased with increasing sulphur levels and the maximum was recorded at 60 kg ha^{-1}. Similar results in sunflower was reported by Dhage and Patil (2008)

The positive influence of sulpur in the oil and protein content of soybean was emphasised by Chaurasiya *et al.* (2009). It had been found that the increasing levels of sulphur significantly increased the protein and oil content in soybean upto 30 kg S ha^{-1}.

2.1.6 Nutrient composition and uptake by oilseeds

The crop removal of S annually under Indian condition is estimated to be 1 million tone, but the replenishment through fertilisers is only 0.3 million tonne. It is relatively an immobile nutrient in the plant (Tandon, 1988). According to Kumpawat and Jain (2007), S uptake is generally 9-15 per cent of the N uptake though it can range from 5 to 30 per cent and the crops absorb nearly as much S as they absorb P. The usual S content in plant dry matter is 0.1-0.4 per cent (Kharub and Dhillion, 2007).

Sulphur application have a significant effect on the nutrient composition of oilseed crops especially with regard to N, P, K, S, Ca and Mg. Applications of S at a rate of 100 kg ha^{-1} increased S uptake in oil seed rape by 10–15 kg ha^{-1} (Zhao *et al.*, 1993).

Dubey *et al.* (1994) reported that S content and its uptake by grain in Indian mustard increased with increasing levels of the nutrient.

Agarwal and Mishra (1994) found that in soybean application of 30-40 kg S ha^{-1} significantly increased the N and S content in plant and grain and that leaves recorded far more content than seeds and grain. The total N:S ratio became narrower with increasing rate of S dose.

Application of S at 10 kg ha^{-1}significantly increased the uptake and concentration of N, P and K in sesame (Nageswar *et al.*, 1995). Similar results in Indian mustard and rapeseed were reported by Purakayastha and Nad (1996) and (Paulsen, 1999 and Mishra *et al.*, 1999) respectively.

Kala and Gupta (1999) studied the comparative response of some rabi crops to S application in Ustipsamment soils of Haryana and found that its application significantly increased the S content of grain and bhusa portions of raya and the content was more for bhusa portion compared to the grain.

Devakumar and Giri (1999) conducted field trials to understand the effect of gypsum application on the content and uptake of N,P, Ca, and S in groundnut and found significant increase in both content and uptake of these nutrients by gypsum application @ 400 kg ha^{-1}.

While analysing the relationship of N, S and Ca in sustainable production of Indian mustard on a denuded land, Singh (1999) found that total uptake of N, S and Ca were significantly increased by the application of S @ 50 kg ha^{-1} and Ca @ 100 kg ha^{-1}.

Devi *et al.* (1999) reported that the application of S at increasing levels significantly increased the content and uptake of N, P, K, Ca, Mg and S in haulm and grain of groundnut. But the S use efficiency decreased from 15.8 to 6.21 per cent due to increase in S level from 15 to 75 kg S ha^{-1}. Nutrient ratios such as, N:S, Ca:S, and Mg:S were narrowed down from 8.8 to 5.7, 10.4 to 6.6 and 4.4 to 2.7 respectively due to increase in S level from 0 to 75 kg S ha^{-1}.

Babhulkar *et al.* (2000) found that the application of S @ 45 kg S ha^{-1} significantly increased the total uptake of N, P, K and S in Safflower. Similar result in canola with the application up to 20 kg S ha^{-1} was reported by (Jackson, 2000).

The positive influence of S on the uptake of nutrients was also reported by Brahmachari and Mondal (2000) in rape seed and Singh *et al.* (2000 a) in niger cultivated in acid soils of Bihar Plateau and Singh *et al.* (2000 b) in gobhi sarson and succeeding crop of soybean.

The increase in concentration of N, K, Ca and S content in grain and bhusa with increase in level of S was reported in sunflower (Agarwal *et al.*, 2000), groundnut (Bandhopadhyay and Smaui, 2000), soybean (Majumdar *et al.*, 2001) and Indian mustard (Raut *et al.*, 2000; Kumar *et al.*, 2001).

The uptake of N, P, K and S in sunflower was synergistically affected by the application of 60-80 kg S ha^{-1} in an Albaquept Soil (Nasreen and Huq, 2002). Similar result in mustard was reported by Misra *et al.* (2002). They also found the narrow N:S ratio in the seeds of different cultivars.

Awlad *et al.* (2003) found that the highest S content in soybean was recorded at 110 DAS with 30 kg S ha^{-1} and the lowest in control.

Application of 40 kg S ha^{-1} significantly increased the content and uptake of N in seed and bhusa of taramira (Singh and Pareek, 2003).

Addition of S significantly increased the nutrient uptake of N, P, K and S in groundnut and the maximum was recorded by gypsum@45 kg S ha^{-1}(Kalaiyarasan *et al.*, 2003).Similar result in groundnut with gypsum @ 250 kg ha^{-1} was reported by Srilatha *et al.* (2004).

The K and S uptake in sesame was positively influenced by the application of S up to 20 kg S ha^{-1} in a light textured inceptisol (Thakur and Patel, 2004).

The concentration and uptake of N and S increased significantly with the addition of 40 kg S ha^{-1} with increasing levels of S in sunflower (Ramu and Reddy, 2004) and mustard (Singh and Meena, 2004; Singh and Jain, 2004; Rana *et al.*, 2005). There was also an improvement in the content and uptake of P and B in the crop.

The S uptake of pods of groundnut increased significantly up to 60 kg S $ha^{-1}$and was found to be 134.7 per cent over control (Singh *et al.*, 2005).

Pandiyan and Annadurai (2005) conducted an investigation to understand the interaction effect of P and S on sesame in a Typic ustochrept soil and found positive response with regard to S applied @ 40 kg ha^{-1} in combination with P @ 100 kg ha^{-1}.

The nitrogen S and phosphorus content and uptake in bhusa and seeds of sunflower were significantly increased by the application of S @50 kg ha^{-1}(Thorat *et al.*, 2005 and Syed *et al.*, 2006).

Piri and Sharma (2006) studied the S uptake pattern in Indian mustard with increasing levels of S and found that content and uptake in seed increased up to 15 kg S ha^{-1} and in the next year, it was up to 30 kg S ha^{-1}. Similar result on increased S uptake with increase in S levels was also reported by Kumar *et al.* (2006). The fertiliser use efficiency of S was higher at lower rates. The response to S varied from 6.7 to 13.6 kg seed per kg S applied.

The highest uptake of N, P, K, with groundnut was obtained by the application of 125 per cent RDF along with gypsum (Dutta and Mondal, 2006).

Govahi and Saffari (2006) reported that total S uptake in spring canola seed significantly increased with the application S @ 0 to 120 kg ha^{-1}.

The seed yield of Indian mustard S showed second polynomial increase with successive increase in S doses. Uptake of S increased with increase in dose of S up to 45 kg S ha^{-1}(Kumar and Yadav, 2007).

The enhanced uptake of S with increase in S dose up to 60 kg S ha^{-1} in groundnut (Singh and Mann, 2007) and brassica oil seed crops with 30 kg S ha^{-1} (Malhi *et al.*, 2007) and mustard with 45 kg ha^{-1} (Kumar and Yadav, 2007) was also documented.

According to Raja *et al.*, (2007 b), the maximum N, K, and S uptake in sesame was obtained with 60 kg S ha^{-1} because increased S uptake accelerated increased N utilization. Maximum P uptake was noticed with 45 kg S ha^{-1} due to the positive interaction i.e., S application might have been increased P availability in soil by reducing the soil pH.

The uptake of N, P, K and S were increased by the application of S @ 30 kg ha^{-1} in rape seed (Basumatary and Talukdar, 2007 and Sarangthem *et al.* 2008), Safflower (Ravi *et al.*, 2008), mustard (Jat and Mehra, 2007 and Sharma and Arora, 2008) and sunflower (Shekawat and Shivay, 2008 and Dhage and Patil, 2008).

The uptake of N, P, K and S by groundnut at harvest was significantly influenced by the application of S at increasing levels from 20 to 60 kg S ha^{-1} (Jena *et al.* 2008).

The synergistic effect of S in the uptake of N, P, K and S in soybean upto 40 kg S $ha^{-1}$was reported by Chaurasiya *et al.* (2009). The crop removal of S had been found to be 11.7 kg $tonne^{-1}$ in sesame (Hegde and Babu, 2009).

2.1.7 Sulphur content in soil

Total sulphur content of lithosphere is about 600 mg kg^{-1} and the total sulphur content among Indian soils ranges between 10 to 6319 mg kg^{-1}, but the mean content is found to be 30-300 mg kg^{-1}oil in most of the agricultural soils (Tandon, 1991). It had also been found that S deficient soils are found in all the districts of Kerala ranging from 20-25 per cent. Total S content Analysis of more than 60 000 surface samples of the country revealed that sulphur deficiency in soils of various states varied from 5-83 per cent with an overall mean of 41 per cent. The information on S status of soils of Kerala is very meagre. Sulphur deficiency has been reported in soils of all districts and ranged from 20 per cent in Thriuvananthapuram to 55 per cent in palakkad districts. Crops grown in many areas are showing significant responses between 9-19 kg grain kg^{-1} sulphur applied in case of oilseeds and 4-10 kg grain kg^{-1} of sulphur applied to pulse crops in various agroecological zones of India (Singh, 2006).

2.1.8 Available nutrient status

Ram *et al.*, (1998) noticed that application of S decreased the soil pH and increased the availability of N,P,K, Ca, Mg and S in a sandy loam soil.

Singh *et al.* (2000a) reported the increased availability of S with increase in level of S after the harvest of lentil.

Jyothi *et al.* (2001) observed that the application of different sources of S as gypsum in sunflower increased the available N, P, K and S in alfisols and was 33.86 per cent and 57.9 per cent for N and P over control and for S it was 95.56 per cent over control.

Rao (2003) found that the application of gypsum @ 250 kg ha^{-1} at sowing or in split dose significantly increased the actual gain of nitrogen in soil after groundnut. It also increased the content of sulphate S in a sandy clay loam soil.

Chitdeshwari and Poongothai (2004) in a demonstration trial studied the effect of S on the nutrient availability of groundnut found that the application of S significantly increased the available nutrient status of the soil.

Singh and Mann (2007) reported that the application of S significantly increased the available S status at the harvest stage of groundnut.

According to Raja *et al.* (2007 b) the available S was found to be higher at higher levels of S but the available nitrogen, phosphorus and potassium status in soil was decreasing with increased levels of S from 0 to 60 kg S ha^{-1} due to enhanced crop growth and development.

Chaurasiya *et al.* (2009) reported that the available nutrients were significantly influenced by the rate of S application. Available N, P, K and S were significantly increased by the increasing rate of S from 0 to 40 kg S ha^{-1}.

2.1.9 Agronomic efficiency

The S use efficiency of groundnut decreased with increasing levels of S and the maximum was recorded at 15 kg S ha^{-1} and the optimum dose of S was found to be 30.75 kg ha^{-1} which gave a response of 1.62 t ha^{-1}(Kalaiyarasan *et al.*, 2003).

Fismes *et al.* (2000) emphasised the essentiality of S fertilization in improving the nitrogen use efficiency of oilseed rape.

Singh *et al.* (2000a) reported that the S Use Efficiency and Apparent Sulphur Recovery of the crop showed an increasing trend with increasing levels of S application up to 45 kg S ha^{-1} and there after showed a decreasing trend in niger which was cultivated in acid soils of Bihar Plateau.

Highest physiological efficiency in gobhi sarson and succeeding crop of soybean was reported with S applied at 20 kg S ha^{-1} compared to 40 kg S ha^{-1} (Singh *et al.*, 2000b).

Sarkar and Saha (2005) reported that the apparent recovery of S in sesame was reduced from 36.4 per cent to 23.2 per cent when S was applied at 25 and 50 kg ha^{-1} respectively. The physiological efficiency increased with increase in level of N and S.

Singh and Mann (2007) reported the enhanced uptake of S with increase in S dose up to 60 kg S ha^{-1} in groundnut. The sulphur use efficiency of groundnut was highest with the application at 20 kg S ha^{-1}, but increase in rate of S showed a decreasing trend of S use efficiency.

2.2 BORON

Among the seven micronutrients essential for crop growth and development, boron plays a vital role in oilseed production. This element is directly involved in the process of fertilization, pollen producing capacity of anther, viability of pollen tubes, pollen germination and pollen tube growth. Mengel and Kirkby (1987) suggested a decrease in biomass of sesame as a result of low boron supply was due to the disturbance in the development of meristematic tissues as a consequence of disturbed protein synthesis. Similar observation in soybean was done under field conditions by Buzetti *et al.* (1990) such that an increase in yield was noticed with an increase of 0.3 ppm of boron in pot culture studies. The deficiency of boron is associated with sterility in legumes and crucifers (Jahiruddin, 1992; Shorrocks, 1997).

2.2.1 Effect of B on growth characters of oilseeds

2.2.1.1 Biometric characters

Boron plays a spectacular role in cell wall structure and plasticity and hence has a positive influence on the vegetative growth which is reflected in the biometric characters. The leaf area of oilseed rape was positively correlated with B supply (Xue *et al.*, 1998).

A positive relation between plant height, branches plant^{-1} and soil applied B in mustard was noticed by Naser and Islam (2001).

Sarker *et al.* (2002) noticed that B applied @4 kg ha^{-1} produced highest plant height and number of branches plant^{-1} in soybean.

Sarkar and Saha (2005) found that the application of B along with N and S to sesame resulted in an increase in the leaf area index of the crop at all growth stages.

Oynlola (2007) showed that increasing levels of B application @4.to 12 kg B ha^{-1}, significantly improved the plant height in sunflower and the maximum was recorded @8 kg ha^{-1} and there after it decreased in Typic haplustalf soil.

Viswakarma *et al.* (2008) reported that the growth characters of groundnut like height and number of branches plant^{-1} were favourably influenced by soil application of B as borax in a sandy loam soil.

The plant height of sunflower was significantly increased by the application of B @2.5 kg ha^{-1}(Ceyhan *et al.*, 2008).

2.2.2 Yield and yield attributes

The essentiality of B in crop nutrition was established by Warrington (1923). B deficiency in higher plants causes adverse effects on cellular functions and physiological processes. It decreases the growth of vegetative or reproductive plant parts.

Application of optimum dose of micronutrient such as B is very essential to sustain crop productivity. Response of groundnut was better when applied with B @ 0.5 kg ha^{-1} as borax (Patil *et al.*, 1987). Takkar *et al.* (1989) found that application of 2 kg B ha^{-1} in acidic soil of Orissa to groundnut gave an yield response of 29.9 per cent.

Schon and Blevins (1990) reported that the foliar application of 1.12 kg B ha^{-1} significantly increased the plant height, number of branches plant^{-1}, and seeds plant^{-1} in soybean.

Soil application of borax @ 5 kg B ha^{-1} resulted in higher sunflower seed yield over control (Rao, 1990). Das (1992) found significant increase in sesame seed yield over control with 0.5% foliar spray of B.

Buzetti *et al.* (1990) and Mahajan *et al.* (1994) observed that both the deficiency and the excess of B will significantly reduce the yield of several crops like soybean and groundnut. They also found that low B supply from soil decreased the tissue B concentration as well as oil content in groundnut seeds. Increase in B concentration decreased the biomass yield in Soybean.

Maximum increase in grain yield of rapeseed was obtained with 1 mg B kg^{-1} which was 43 per cent more over control and for mustard the maximum yield was 36 per cent over the control with 1.5 mg B kg^{-1}(Rashid *et al.*, 1994).

Bhilegaonkar (1995) found that seed yield and dry matter production of safflower increased with increasing levels of B upto 10 kg B ha^{-1}. The highest value for harvest index was also obtained with the soil application of borax @ 10 kg B ha^{-1}.

Sakal and Singh (1995) found that the seed yield of sesame increased significantly by increasing levels upto 2 kg B ha^{-1}.

Blamey *et al.* (1997) reported an increase in seed yield of sunflower with the application of B fertilizer in soils consistently low in B supply.

While studying about the differential response of oil seed rape cultivars to low B supply Xue *et al.* (1998) observed its positive influence on the yield and yield attributes of oilseed rape.

Pageau *et al.* (1999) reported that application of increasing levels of B significantly increased the grain yield of canola.

Saha *et al.* (1999a) observed that the application of borax @5 kg B ha^{-1} recorded the highest seed yield in yellow sarson grown in sandy loam soil and that the soil application gave higher seed yield than foliar application.

Sinha *et al.* (1999) reported that application of B@ less than or greater than 0.33 mg litre^{-1} decreased the biomass yield and oil content of sesame seeds. The visible symptoms of deficiency appeared up to 0.165 mg B litre^{-1} and that of toxicity appeared at 0.33 mg B litre^{-1}. They also found that B concentration in leaves were higher than that in seeds irrespective of the B levels This was attributed to the immobility of B in plants (Mengel and Kirkby,1987).

Spectacular response in the yield of groundnut towards B application was reported by Sahu *et al.* (1998).

Nel (2001) identified B as one of the determinants for the seed quality of sunflower and noticed that B fertilization improved its seed yield with an increase of 25 per cent higher than of the control.

Naser and Islam (2001) while studying the response of mustard to different levels of B fertlisation noticed that the application of B significantly influenced number of pods plant^{-1}, seeds per pot, thousand seed weight, seed yield and stover yield. The highest seed yield was obtained with the application of 1.5 kg B ha $^{-1}$ in association with site specific recommended doses of N, P, K, S and Zn fertilisers.

To evaluate the efficiency of different levels of S and B on the performance of sunflower hybrid grown in red sandy loam soils of Karnataka, Reddy *et al.* (2002) conducted a field experiment and concluded that the application of 0.2 per cent borax along with 100 per cent RDF and 500 kg gypsum ha^{-1} recorded 13.5 and 12.3 per cent increase in seed yield and oil yield respectively over control.

Sarker *et al.* (2002) found that different levels of B had a significant effect on the yield and yield attributes of soybean. It had been observed that B applied @ 1 kg ha^{-1} produced the maximum number of pods $plant^{-1}$, and seeds pod^{-1}, and that applied @ 2 kg ha^{-1} produced the maximum test weight which were much significant over the control treatment.

Shankhe *et al.* (2002) conducted a field experiment to evaluate the effect of B on the yield of groundnut and reported that application of B @1 kg ha^{-1} resulted in higher dry matter content, dry kernel yield and crop quality.

Renukadevi *et al.* (2002) studied the efficiency of different sources of B on the performance of sunflower and reported that application at increasing levels from 0.5 to 2.0 kg B ha^{-1} resulted in significantly higher yield of sunflower. The highest yield in terms of seed and stalk was recorded for the soil application at a rate of 2.0 kg B ha^{-1} and was 3.6 to 15.8 per cent and 7.2 to 18.9 per cent over control.

A significant increase in pod and haulm yield, kernel weight and shelling per cent of groundnut was obtained by the application of 0.2 per cent B (Shankar *et al.*, 2003).

Renukadevi *et al.* (2004) observed that the grain and haulm yield of sunflower and subsequent green gram crop increased significantly with increasing levels of B and was maximum when applied @ 2 kg ha^{-1} which was 13.5 per cent more over control.

Sarkar and Saha (2005) reported the favourable influence of B on the biomass yield of sesame. It had been found that the grain yield of sesame was 10.4 per cent more over control when treated with 1 kg B ha^{-1} in entisol.

Rana *et al.* (2005) concluded that B application as 0.2 per cent spray at 50 per cent flowering stage in Indian mustard recorded a marked improvement in seed yield (10.6%), and its attributes like silique $plant^{-1}$, seeds $silique^{-1}$, and thousand seed weight. Hence this recorded more net returns (13.9%) and benefit:cost ratio (4.8%) compared to that of control.

Based on the results of five field trials conducted to study the influence of B on sesame, Singh (2006) found that the per cent response over NPK alone is 23.9 per cent.

Ross *et al.* (2006) reported that the application of 0.28 to 1.12 kg B ha^{-1} during early vegetative or reproductive growth in soybean was sufficient to produce near maximal yields. B fertiliser was applied at rates ranging from 0 to 2.24 kg ha^{-1} which showed an increase in the yield to the range of 4 to 130 per cent.

Shirpurkar *et al.* (2006) found that application of B along with farm yard manure, recommended dose of fertilisers and other micronutrients significantly contributed to the yield and its attributing characters of soybean such as number of pods, number and dry weight of nodules, grain weight, shell weight $plant^{-1}$, hundred seed weight, grain and bhusa yield resulting in increased productivity of the crop.

Cirak *et al.* (2006) conducted experiments regarding the response of soybean to soil and foliar applied B and found that increasing B rate either as soil or as foliar improved its yield and yield attributes like thousand seed weight up to 1.5 kg ha^{-1} and there after showed a decreasing trend. Significant improvement in the first pod height was also observed with the application up to 2 kg ha^{-1}.

Halder *et al.* (2007) studied the response of mustard to B fertilization in non calcareous soil and found that the highest seed yield of 2.23 t ha^{-1} was recorded with 2 kg B ha^{-1} which was statistically significant over the control. A linear relationship between seed yield and the levels of B was observed.

Oynlola (2007) standardized the optimum B rate for sunflower as 5.60-8.40 kg B ha^{-1} in low activity clay soil, Typic Haplustulf for superior yield and yield attributes like seed yield and capitulum diameter. Superior yield was obtained with 8 kg B ha^{-1} and no significant benefits were obtained with 12 kg B ha^{-1}.

The yield attributes of groundnut like maximum number of pods per plant and pod and kernel yield were positively influenced by the soil application of borax (Vishwakarma *et al.*, 2008).

A pot culture study was performed by Srinivasan and Angayarkanni (2008) to study the effect of different levels of B on the yield and dry matter production of groundnut and observed that pod yield, dry matter production, and number of nodules significantly increased with the increase in B rate up to 15 kg ha^{-1}.

A substantial increase in the grain yield of rape seed and mustard was recorded with B fertilization (Karthikeyan and Shukla, 2008). Similar result in the grain yield of sunflower with 7.5 kg B $ha^{-1}$was reported by Ceyhan *et al.* (2008).

Yang *et al.* (2009a) showed that the application of B significantly increased the seed yield which was attributed to an increase in the number of seeds per pod and pods per plant. During the seed development period, dry matter accumulation of seed followed a typical S-shaped curve with the application of B, but seed weight accumulated faster in plants supplied with sufficient B than those with low B. The dry weight of the pod wall in high B treatment showed rapid increase at the early stage of seed development and decreased rapidly in later periods compared with low B.

Yang *et al.* (2009 b) found that the effect of B fertiliser on the seed yield of rape seed was attributed to an increase in the number of seeds $silique^{-1}$ and siliques $plant^{-1}$.

2.2.3 Oil content and quality

Saeed and Woodbridge (1981) noticed a decrease in sugar concentration in sesame seed with increase in B supply. The reduction in protein content of groundnut associated with the deficiency of B was reported by Dave and Kannan (1980) and Esteban *et al.*(1985). This was also reported by Sinha and Chatterjee (1994). The importance of B in improving the quality attributes of oil seeds was also emphasised by Malewar *et al.* (2001).

Boron is involved in oil synthesis and plays a key role in improving the quality of oil seeds (Mahajan *et al.*, 1994).

Sakal and Singh (1995) found that the oil content of most of the oilseed crops increased significantly due to B application.

At higher concentration of B in the range of 3.3 mg per litre, marginal chlorosis and necrosis were reported in sesame leaves (Sinha *et al.*, 1999).This was also followed by decreased biomass, seed yield and oil content. The concentration of carbohydrates, phenols and protein decreased in sesame seed at excess B.

According to Pageau *et al.* (1999), B fertilization at 1 kg ha^{-1} significantly increased grain oil content in canola.

Saha *et al.* (1999a) reported that the application of borax@ 5 kg B ha^{-1} almost doubled the oil yield in yellow sarson grown in sandy loam soil.

Dube *et al.* (2000) studied the effect of B stress on the metabolism and seed quality of sunflower and found a decrease in starch content and an increase in the activity of catalase, peroxidase, acid phosphatase, aldolase, and ribonuclease together with an accumulation of sugars (reducing, non-reducing, and total) and nitrogen fractions (protein and non-protein).

Boron deficiency reduced flowering, dry matter, pod yield, tissue B, chlorophyll content, Hill reaction activity, protein and organic labile, and lipid phosphorus fractions, and increased the concentration of inorganic phosphorus, reducing and non-reducing sugars, phenol content, and the activities of peroxidase, acid phosphatase, and ribonuclease in mustard (Khurana and Chatterjee, 2002).

To evaluate the efficiency of different levels of S and B on the performance of sunflower hybrid Reddy *et al.* (2002) conducted a field experiment and concluded that the application of 0.2 per cent borax along with 100 per cent RDF and 500 kg gypsum ha^{-1} recorded 12.3 per cent increase in oil yield over control in sunflower hybrids grown in red sandy loam soils of Karnataka.

A significant increase in protein content from 27.37 to 29.31 per cent and oil content from 46.23 to 48.45 per cent were observed in groundnut by Shankhe *et al.* (2002)

Renukadevi and Savithri (2003) found that soil application of 2 kg B ha^{-1} increased the oil content, oil yield and seed protein content of groundnut by 8.1, 22.3 and 25 per cent respectively. They also observed that B application had no significant effect on iodine value, saponification number and acid value of sunflower.

Boron accelerates protein synthesis and is involved in a number of metabolic pathways or a cascade effect. The beneficial effect of spraying with B may be attributed to the role of B on fundamental metabolic reactions and acceleration protein synthesis, also B is involved in a number of metabolic pathways (sugar transport, respiration, carbohydrate, RNA, IAA and phenol metabolism or a cascade effect which is known for photohormones. Nasef *et al.* (2006) observed that the oil and prótein content in groundnut increased significantly increasing levels of foliar spray with B up to 300 ppm as compared to control.

Oynlola (2007) found that the oil content in sunflower was maximum @ 8 kg B ha^{-1} and recorded an increase of 23.2 per cent over control.

2.2.4 Nutrient content and nutrient uptake

Boron has a positive influence on the absorption of N,P, K and its deficiency changed the equilibrium of optimum dose of these macro nutrients (Raj, 1985).

Boron fertilization increased the B concentration in whole shoots, recently matured leaves, mature grains and bhusa of rapeseed and mustard. The concentration in foliar parts were higher than that in seeds (Rashid *et al.*, 1994).

Sakal *et al.* (1999) found that the increasing levels of B applied as borax increased the content and uptake of bom in the grain and bhusa of both maize and lentil in a cropping system.

Boron concentration of canola leaves increased with B fertilization at the flowering stage (Pageau *et al.*, 1999).

Saha *et al.* (1999b) reported that increasing B application did not always result in higher concentrations in plant tissue in yellow sarson possibly due to dilution effects from increased dry matter yield.

The concentration of B was increased in leaves, flowers, and seeds with an increase in B supply but B concentration in seeds was less marked than in leaves and flowers (Dube *et al.*, 2000).

Renukadevi *et al.* (2004) reported that as the level of application of B increased the content and uptake in grain and bhusa of green gram also increased, the highest value was recorded when applied at 2 kg B ha^{-1}.

The removal of B in the grain and bhusa of gram significantly increased with the increase in level of application of boron and lime up to 1 kg B ha^{-1} which was statistically at par with that of 2 kg B ha^{-1}(Singh *et al.*, 2004).

Sarkar and Saha (2005) reported that the physiological efficiency was highest with 1 kg B ha^{-1} in sesame.

The B content of soybean seeds increased with increasing rate of application which resulted in increased germination per cent (Cirak *et al.*, 2006).

Ross *et al.* (2006) reported that as the rate of B concentration increased from 0, 0.28, 0.56, 1.12, and 2.24 kg ha^{-1}, the trifoliate leaf B concentration and that of seed B content increased in soybean.

Nasef *et al.* (2006) observed that the foliar spray with B at increasing levels from 100 to 300 ppm significantly increased the uptake of N, P, K by bhusa and seeds of groundnut plants grown in a sandy soil. It has also been reported that the foliar application significantly increased the uptake of Fe, Mn and Zn and B by the bhusa and seeds compared to that of the control. This result may be due to B which is involved in the physiological processes controlling the uptake and transport of Fe, Mn and Zn and also in the mobilization of reserve proteins.

Duraisami *et al.* (2007) observed that application of B @ 1.5 kg ha^{-1} increased the uptake and content of B in grain and stover of maize grown in alfisols.

Sarkar *et al.* (2007) found that the B concentration in plants and its uptake increased with B application being highest in mustard, followed by potato and wheat.

Increasing the level of B application significantly increased the concentration of B in leaf (Ceyhan *et al.*, 2008).

The uptake of B in French bean was maximum with the application of B@10 kg ha^{-1} as borax (Kumar *et al.*, 2008a).

Nitrogen and potassium content and uptake in plant tops of soybean increased gradually with increasing rate of B application upto 1.5 kg $ha^{-1}$and there after it decreased with increasing rate such as 2,2.5,and 3 kg B ha^{-1} where as the uptake and content of phosphorus was highest with 1 kg B ha^{-1}which was 12.5 percent over the control

Rana *et al.* (2005) concluded that B application as 0.2 per cent spray at 50 per cent flowering stage of Indian mustard recorded a marked improvement in seed yield (10.6%), and its attributes like silique $plant^{-1}$, seeds $silique^{-1}$, and thousand seed weight, uptake of P (8.3%), S (7.30%) and B (14.3%), and net returns (13.9%) and benefit:cost ratio (4.8%) compared to that of control.

2.2.5 Available nutrient status of soil

Asad *et al.* (1997) reported that B inhibits calcium absorption in canola as it was observed that increase in B applied decreased the calcium uptake rate. .

The available B status of soil was favourably influenced by the application of borax either alone or in combination at increasing levels and the highest value was recorded with the application of 64 kg borax along with 5 t FYM ha^{-1}(Sakal *et al.*, 1999).

Renukadevi *et al.* (2004) reported that application of B@ 2 kg ha^{-1} recorded significantly higher hot water soluble B followed by 1.5 kg ha^{-1} in soil typic ustropept.

Boron deficiency under Indian condition ranged from 2 and 69% (Malewar, 2005). The status of boron in Indian condition ranged between 0.05 to 6.67mg kg^{-1} with a mean of 0.78mg kg^{-1}(Singh, 2006).

2.3 INTERACTION EFFECT OF S AND B ON OILSEEDS

2.3.1 Yield and yield attributes

The positive response of oilseed crops like Rai and groundnut towards the application of S and B was reported by Shukla *et al.* (1983) and Karle and Babula (1985).

Significant increase in yield and yield attributes of legumes and oil seeds due to the combined application of S and B was reported by Chatterjee *et al.* (1985) and Sakal *et al.* (1987).

In mustard, Khurana and Chatterjee(2002) found that B deficiency at normal sulfur reduced flowering, dry matter, pod yield, tissue B, chlorophyll content, Hill reaction activity, protein and organic labile, and lipid phosphorus fractions, and increased the concentration of inorganic phosphorus, reducing and non-reducing sugars, phenol content, and the activities of peroxidase, acid phosphatase, and ribonuclease. A synergism between B and S was reflected when B deficiency effects were accentuated further by combined deficiency of both nutrients. No seeds were formed in B deficiency regardless of sulfur levels. The foliar symptoms of B excess were initiated earlier than its deficiency and were more severe at low S levels. At excess B, the decreases in biomass, pod yield, chlorophyll, and lipid P concentrations were more pronounced at low S level. Also an increase in leaf B, reducing and non-reducing sugars, phenols, and activity of ribonuclease and peroxidase occurred, indicating a synergistic role of B and S in mustard.

Sarker *et al.* (2002) reported that yield and yield attributes of soybean were significantly influenced by the application of S and B. The highest biological yield and most of the yield attributes were obtained for the treatment combination of 30 kg S and 1.0 kg B ha^{-1}. Grain yield was found to be significantly and positively correlated with effective pod and seed $plant^{-1}$ and harvest index. Uptake of S and B by grain was significant by both S and B application individually. Protein and oil contents of soybean grain were increased with increasing levels of both S and B. The overall results suggested that S and B @ 30 and 1.0 kg ha^{-1} alone or in combination proved to be the best in respect of the parameters studied. The highest plant height and pod length were obtained by the application of S @10 and 50 $kgha^{-1}$ and B @ 4 and 2 kg ha^{-1} respectively in soybean.

Sarkar and Saha (2005) found that the application of S @ 50 kg ha^{-1} along with B @ 1 $kgha^{-1}$ increased the seed yield of sesame in an entisol.

In sandy loam soils of Haryana, mustard and chick pea gave significant yield response with the application of Zn, S and B (Singh, 2006).

Kumar *et al.* (2006) found that the yield and yield attributes of gram were significantly influenced by the combined application of B and S. The highest number of pods $plant^{-1}$ and test weight were recorded with 10 kg borax ha^{-1} along with 30 kg S ha^{-1}. This also recorded the maximum seed and bhusa yield in gram.

Singh *et al.* (2006) reported that the seed and stover yields of soybean were significantly influenced by graded levels of S and B application@ 60 kg S ha^{-1} and 2.0 kg B ha^{-1}. The crop yield increased more due to S as compared to B application. The total S and B uptake by crop increased significantly with increased levels up to 60 kg S ha^{-1}. The total S uptake at 0 and 60 kg S ha^{-1} was 10.27 and 16.72 kg ha^{-1}, respectively, whereas total B uptake at 0 and 2.0 kg B ha^{-1} was 98.58 and 198.72 kg ha^{-1} respectively. This clearly depicts the synergistic role of these nutrients in improving the yield and yield attributes of oil seeds.

Shekawat *et al.* (2008) reported that the combined application of S and B along resulted in larger head size, higher number of seeds per capitulum, higher seed weight per capitulum and higher thousand seed weight in sunflower.

2.3.2 Dry matter production

Karthikeyan and Shukla (2008) reported that the interaction between S and B significantly and synergistically influenced the dry matter and seed yield of sunflower and mustard and the combination of 60 mg kg^{-1} S and 2 mg kg^{-1} B was found to be the best.

2.3.3 Nutrient content and uptake by oil seeds

Gangadhra *et al.* (1990) reported that the application of S at higher dose increased the uptake of other elements including B in sunflower stalk in Typic Chromustert.

Kumar *et al.* (1994) observed that the application of S increased the S uptake by safflower and mustard.

Chakraborty and Das (2000) also found an increase in B and S uptake by the mustard seeds with increasing levels of S and B as well in combination of S up to S @ 60 mg kg^{-1} and B @3mg kg^{-1} in a silty loam soil.

A synergistic interaction between Zn and B was reported in mustard by Malewar *et al.*, (2001). The highest S and B uptake in the grain of soybean was observed with S applied @10 and 20 kg ha^{-1} respectively and the lowest values were obtained from no S application (Sarker *et al.*, 2002).

The uptake and concentration of S and B in gram was highest with the application of 10kg borax/ha and with 30 kg S ha^{-1}(Kumar *et al.*, 2006).

Results of a front line demonstration showed that application of 1 kg B ha^{-1}, and 40 kg S ha^{-1}significantly increased the pod yield of groundnut by 14.35 per cent in an Ustipsamment soil (Singh, 2006).

Application of 60 mg kg^{-1}S and 3 mg kg^{-1}B significantly increased the B uptake by bhusa and seed in sunflower. S uptake by sunflower seed and bhusa increased with increasing levels of S and the maximum was recorded with S @ 60 mg kg^{-1} and B @ 2 mg kg^{-1} and was on par with the highest level at 3 mg kg^{-1}B. The dry matter and seed yield of mustard increased significantly with increasing levels of S and B and the highest was obtained with 2 mg kg^{-1}B and 60 mg kg^{-1}S. The highest per cent increase in mean sunflower and mustard seed yield was about 141 per cent with the highest level of S @ 60 mg kg^{-1} and 34 per cent at highest level of B applied @ 3 mg kg^{-1}. As far as the interaction effect of B and S is concerned, a significantly higher seed of mustard was obtained by the application of 60 mg kg^{-1} S in combination with 2 mg kg^{-1} of B which was three times more than control (Karthikeyan and Shukla, 2008).

The increased uptake of nutrient by the combined application of S and B in sunflower was reported by Shekawat *et al.* (2008). They found that the application of various treatments significantly enhanced the total uptake of N, P, K, S and B by spring sunflower crop.

2.3.4 Quality parameters

A synergism between B and sulphur was reflected when B deficiency effects were accentuated further by combined deficiency of both nutrients in mustard. No seeds were formed in B deficiency regardless of sulfur levels. The foliar symptoms of B excess were initiated earlier than its deficiency and were more severe at low sulfur levels. At excess B, the decreases in biomass, pod yield, chlorophyll, and lipid P concentrations were more pronounced at low sulfur level. Also an increase in leaf B, reducing and non-reducing sugars, phenols, and activity of ribonuclease and peroxidase occurred, indicating a synergistic role of B and S in mustard (Khurana and Chatterjee, 2002).

Poongothai and Chithdesheari (2003) observed that the soil application of 1.5 kg B ha^{-1}, 40 kg S ha^{-1}, 5 kg Zn and 0.5 kg Mo significantly enhanced the availability of these nutrients in a red sandy lam soil which was previously deficient in these nutrients.

Singh *et al.*, (2006) concluded that the oil and protein content of soybean increased with increasing levels of S and B and the maximum was recorded with 40 kg S ha^{-1} along with 0.5 kg B ha^{-1}.

Karthikeyan and Shukla (2008) found that the oil content of sunflower seeds were synergistically influenced by the application of S and B and increased from 33.2 per cent in control to 39.6 per cent at 60 mg kg^{-1} of S application and that the content increased from 34.4 per cent to 39 per cent with increasing levels of B application. The interaction effect of B and S synergistically influenced the oil content of sunflower seeds, which was observed to be 41.5 per cent @ 2 mg kg^{-1} of applied B in conjunction with 60 mg kg^{-1} of S. Similar trend was observed in mustard also.

2.5 INTERACTION EFFECT OF SULPHUR WITH OTHER NUTRIENTS

Beena (2000) reported that by the application of gypsum @ 30 kg S ha^{-1} the exchangeable calcium, magnesium and available S were increased in red and laterite soil of Vellayani.

The interaction effect of P and S revealed that by increasing the P levels, available S got increased irrespective of S levels (Pandiyan and Annadurai, 2005).

The nitrogen S interaction significantly affected the crop yield and the uptake of N and S in sunflower by the application of N @ 80 kg ha^{-1} and S@ 60 kg S ha^{-1}(Syed *et al.*, 2006).

McGrath and Zhao (1996) reported that large increases in seed yields, to the range of 42-67 per cent, were obtained in response to the application of 40 kg S ha^{-1} along with nitrogen applied at 180 and 230 kg ha^{-1} in winter oil seed rape.

Malhi and Gill (2007) studied the interaction between S and N on the yield and its attributes of canola and found that in the absence of S application, increasing N rate made the S deficiency symptoms more severe, which in turn reduced yield, S concentration, oil concentration, S uptake and N uptake of seed. On the other hand when S was applied all these parameters showed an increasing trend.

Sahrawat *et al.* (2008) reported widespread deficiency of sulphur and boron in the semi arid regions of India.

2.6 INTERACTION EFFECT OF B WITH OTHER NUTRIENTS

The interaction between B and S had been found to be synergistic. B and S application gradually increased the B concentration in groundnut kernels (Sakal *et al.*, 1987).

A synergistic relationship was observed between B and P in mustard (Saha and Haldar, 1998).

Uddin *et al.* (2003) observed a positive interaction between nitrogen and B on the yield of chilly and the optimum rate was found to be 120 kg N and 2.5 kg B ha^{-1}.

Shaaban *et al.* (2006) noticed a positive interaction between levels of B and N @ 40kg N ha^{-1} and 25-50 ppm B on the biometric characters of pea plants like plant height, leaf area, total dry weight and the yield attributes like increased number of pods, number of seeds per pod, seed yield.

Chander *et al.* (2006) reported that the application of B along with farm yard manure recorded a consistent increase in available P only in the initial period and there after it decreased both in the incubation study and green house trials.

Hosseini *et al.* (2007) found that the effect of B and Zn interaction was antagonistic on nutrient concentration and synergistic on growth of corn and hence the plants have to be adequately supplied with zinc when it is grown in high B soils, especially when the availability of zinc is low.

K interacts synergistically with B. There is also an interaction of S with Zn, Mo, and Ca. The interaction of N and S, P and S, B and S, S and Zn, P and Zn etc are of greatest importance in terms of yield and quality of oilseeds (Hegde and Babu, 2009).

2.7 FOLIAR DIAGNOSIS AS A TOOL IN SOIL FERTILITY EVALUATION

Plant analysis for diagnosing nutrient deficiency is based on the assumption that growth and yield will be reduced when the concentration of a nutrient falls below a certain critical per cent (Ensminger and Freney, 1966) and this per cent depends on the age of the plant and the nutritional status of the soil. The vegetative index provides an indicator of metabolic activity in the plant during the biological cycle, when the growth, flowering, fertilization, fruit development and ripening stages occur in rapid succession.

The tissue sampling techniques for crops are standardized by Chapman (1975).The factors associated with the concentration of nutrients in index tissue or leaf are part of the plant, age of the leaf, part of the leaf, size of leaf, leaf supporting new growth, vegetative or flowering shoot, flush, cultivar, crop load, size of plant, health of leaf, size of sample, variation among plants (Bhargava, 2002).

Foliar analysis can be an effective tool for planning and monitoring operational fertilization projects. Foliar analysis information can be used to: 1) diagnose possible nutritional reasons for poor quality or rate of tree growth; 2) identify stands that will likely respond well to nutrient additions; 3) prescribe fertiliser formulations to correct inferred nutrient deficiencies and stimulate tree growth; and 4) assess post-fertilization uptake of applied nutrients and foliar nutrient balance (Brockley, 2001).

2.7.1 Foliar diagnosis of S and B

Monitoring the nutrient status of a crop by tissue analysis is an important tool in maximizing yield and avoiding nutrient deficiencies or toxicities. Diagnosis is the determination of nutrient status in the plant at the time of sampling (Smith, 1986) with the objective of positively identifying a disorder.

Analysis of B concentration in the plant or specified part of the plant can provide such a positive diagnosis if the B concentration is below a defined standard B concentration. For diagnosis, the standard B concentration should be one related to the physiological requirement for B in the plant part. That is, the standard needs to be established by relating the internal B concentration in the plant pat to a physiological or growth function which is clearly regulated by the B concentration in the plant part. Such standards were defined by Loneragan (1968) as functional nutrient requirements (Bell, 1997). It was also suggested that for diagnosis, an ideal plant part for sampling would have a constant critical concentration with plant age and should respond to increasing B supply. In species which cannot translocate B, young growing plant parts are preferred for diagnosis. The range between levels of soil B causing deficiency and toxicity in plants is rather small, hence B fertilization in deficient plots require due attention (Keren and Bingham, 1985). The nutrient indexing of S in groundnut was carried out by Rashid *et al.* (2000).

2.8 STANDARDISATION OF INDEX TISSUE FOR S AND B

2.8.1 Sulphur

Hitsuda *et al.*, (2004) observed the seed S concentration as a more reliable index of seed yield because of the higher correlation between S concentration and yield in soybean.

Muchovej *et al.* (2005) suggested removing the midrib in the sampling process because most critical values or standard indices have been developed using sampling methods that remove the midrib. The analytical values for most nutrients are lower when the midrib is included in the sample.

2.8.2 Boron

Yousif *et al.* (1972) observed the correlation between the B content of leaf blades, petioles, and stems and substrate B in sesame. The leaf blades contained the highest amount of B, and the stems the least. Concentrations of 5 mg B $litre^{-1}$ or higher inhibited growth, seed production, and resulted in a leaf necrosis and premature leaf drop. Foliage of plants receiving excess B contained greater than 700 μg B g^{-1} on a dry weight basis

In walnut, in which B is immobile, the highest B accumulation occurred at the tip and margin of leaf (Brown and Hu, 1992).

Huang *et al.* (1996a) suggested the use of youngest open leaf of canola for diagnosis of B deficiency. They also standardized the youngest open leaf in rape seed as the most reliable index to diagnose B deficiency and the critical limit had been found out as 10-14 mg B kg^{-1} dry matter.

Mcgrath and Zhao (1996) reported that the concentration of S in leaves of winter oil seed rape at early flowering was found to be the best index in predicting S deficiency in terms of seed yield and a critical value of 3.8 mg g^{-1} was obtained.

Pinkerton (1998) standardized shoots and youngest fully expanded leaves in oil seed rape for tissue analysis which were the most satisfactory indices of rapeseed S status for diagnosis and yield prediction.

James *et al.* (2001) established a correlation between B efficiency and the ratio of the B concentration in the younger relative to the older leaves that the concentration of B in the older leaves decreased with plant age, whereas when sufficient B was supplied, the concentration in these leaves continued to increase with age.

The plot of Bray's per cent yield against soil available B indicates 0.53 mg kg^{-1} as the critical limits below which response to boron application can be expected (Murthy, 2006).

Razeto and Castro (2006) reported that inflorescence can be used to diagnose the B status of avocado trees more accurately than the current standard May leaf sample in avocadoes.

Sulphur content in the young fully developed leaves of 40-45 days old oil seed crop below 0.15, 0.15-0.3, 0.3-0.45 and above 0.45% are categorized as severely S deficient, deficient, moderately sufficient and sufficient crops respectively (Hegde and Babu, 2007).

Razeto and Castro (2007) standardized peduncle and fruit pulp of avocado for diagnosing the B status of avocado trees and reported them as better indicators than leaf tissues.

Mahler and Shafii (2007) found that the critical soil B value for optimum yield of lentil as 0.4 µg/g in Mollisols and Alfisols.

Ezenwa *et al.* (2008) reported that the top visible Top Leaf Blade as the preferred tissue for doing foliar analysis of B in sugarcane.

The plant parts standardized for diagnosis of B include flowers in grape vine (Fregoni, 1980), hull in almond (Nyomara and Brown, 1997), fruit peduncle and pulp in avocadoes (Razeto and Castro, 2007).

2.9 CRITICAL NUTRIENT CONCENTRATION OF S AND B

Critical nutrient values as used above are often defined as the concentration of the nutrient in a particular soil or plant fraction at 95% of the maximum yield. Kanwar and Randhwa (1974) reported 57.2 mg kg^{-1} as the threshold value for boron deficiency in groundnut plants.

2.9.1 Sulphur

Critical nutrient values for S have been derived from leaf tissue analysis in oil-seed rape (Haneklaus and Schnug, 1994). A total S concentration below 0.35 per cent S in young, fully developed leaves during stem extension is in the range of severe S deficiency. Between 0.35 and 0.55 per cent S, growth is retarded but no macroscopic symptoms are visible, and maximum yield will be obtained at a total S concentration of 0.65 per cent, corresponding to a critical value of 0.55 per cent.

Hitsuda *et al.* (2004) found that the critical seed S concentration for deficiency of protein components in soybean was 2.0 g $kg^{-1}$and identified the critical concentration as 2.3 g kg^{-1} for more than 90 per cent yield.

The critical sulphur concentration in the shoots of canola was found to be 6 g kg^{-1}in the rosette stage which declined to about 4.4 g kg^{-1} at the flower buds visible growth stage (Brennan and Bolland, 2008).

Kumar *et al.* (2008 b) suggested that the critical level of sulphur in green gram as 11.6mgkg^{-1} as estimated by statistical procedures of Cate and Nelson (1965) and by graphical procedures the limits were 9.5 and 33.8 mg kg^{-1}.

According to Hegde and Babu (2009), soil testing below 10 mg kg^{-1} have been considered as sulphur deficient. The critical value of 0.15 per cent $CaCl_2$ extractable sulphur was estimated as 10.6, 5.6, 12.5, and 10 mg kg^{-1} for pigeon pea, cluster bean, wheat and chick pea respectively.

2.9.2 Boron

In the Critical Value approach, the critical concentration of a nutrient is the point at which plant growth is reduced by 5 or 10 per cent from optimum and below which deficiency symptoms appear (Ulrich and Hills, 1973). This approach may also include the use of the optimum range, defined as the range of nutrient concentration that is considered optimum for production. Within this range, a particular nutrient is not considered to limit production. Blamey (1975) found that 10, 47 and more than 103 mg kg^{-1} of boron concentration in the mature top leaf of sunflower at flowering stage as the deficiency, sufficiency and toxicity limit respectively. Sillanappa (1991) reported that the upper limit of the critical nutrient range for boron sufficiency in soil is 2 mg kg^{-1}.

Rashid *et al.* (1994) reported that the critical B concentration in rape seed as 32 mg kg^{-1} in whole shoots and in recently mature leaves, it was 38 mg kg^{-1} and that of mustard it was 41 and 49 mg kg^{-1} respectively. Wei *et al.* (1998) selected the youngest open leaf of oil seed rape as the sampling part to analyse the critical B concentration as its B concentrations were strongly responsive to increasing B supply and well correlated with seed yield response. The calculated critical range in the youngest open leaf at seedling stage was 20-25 mg B kg^{-1}.

Huang *et al.* (1996a) estimated that critical concentrations for boron deficiency diagnosis were 10 to14 mg B kg^{-1} dry matter in the youngest open leaf, and 6 to 8 mg B kg^{-1} dry matter in the youngest mature leaf of canola.

The critical B range for prognosis of B deficiency was found to predict consistently those crops in farmer's fields that had low seed yield and low soil B, but needs to be evaluated in other growing environments especially those for spring rape. It has been reported that the values of deficiency, threshold of deficiency and the threshold of toxicity in leaves of sesame were 15.5, 27.0 and 74.0 microgram per gram of dry matter respectively (Singh *et al.*, 1999).

Wei (2001) reported that the critical range of the B concentrations in soil corresponding to 90 percent of the maximum rape seed yield was approx 0.52 mg kg^{-1}.

The critical nutrient concentrations in plants were total sulphur -0.20–0.25 per cent and sulphate sulphur 230–460 mg kg^{-1} at the rosette stage. About 52 per cent of the soil S critical levels are in the range of 8-12 mg kg^{-1}(Messick, 2002).

Dube *et al.* (2000) reported that the values of deficiency, threshold of deficiency, and toxicity were, respectively, 12.5, 27.0, and 89 μg g^{-1} B in leaves of sunflower.

Zerrari and Moustaoui (2005) reported that the 32.5 c mol B kg^{-1} dry matter separates deficient concentrations from satisfactory concentrations in sunflower and that soils on which deficient plants have been observed are characterized by clay contents of less than 30.7 per cent and cation exchange capacity of less than 24.5 cmol 100 g^{-1} soil. On the other hand, if tissue concentrations are below 32.5 mg boron kg^{-1} dry matter, plants show a response to boron. It has also been reported that for the correction of deficient plants with concentrations between 16.5 and 23.0 mg B kg^{-1} dry matter requires the application of 300 g B ha^{-1}, while those with concentrations between 23.0 and 32.5 mg B kg^{-1}dry matter require 150 g B ha^{-1}.

The critical nutrient concentration in whole shoots of sweet pepper was determined by Nabi *et al.* (2006) as 69 mg B kg^{-1} for three-week-old plants and 49 mg B kg^{-1} for six-week-old plants.

Jyolsana and Mathew (2008) reported that application of 0.5 kg ha^{-1} resulted in the critical boron range in laterite soil. They suggested the application of Boron @0.5 kg ha^{-1} in the laterite soils of South Kerala.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Investigations were carried out at College of Agriculture, Vellayani and at Onattukara Regional Agricultural Research Station, Kayamkulam, to study the effects of two essential elements S and B on the growth, yield and quality characters of sesame in Onattukara sandy soil of Kerala and to standardize the foliar diagnosis techniques for these elements.

The research programme was scheduled in two steps:

1) Incubation study at College of Agriculture, Vellayani
2) Field experiments at Onattukara Regional Agricultural Research Station, Kayamkulam

The details regarding the laboratory and field experiments conducted, observations recorded, analytical methods used and statistical procedures followed for achieving the objectives are presented in this chapter.

3.1 INCUBATION STUDY

The laboratory study was conducted from June 2007 to July 2007 at College of Agriculture, Vellayani, incubating the soil brought from ORARS, Kayamkulam with graded levels of S and B each alone or in combination. The basic analysis of the soil for the important physico chemical properties was done according to the standard procedures outlined in Table1.

Gypsum ($CaSO_4.2H_2O$ containing 18% S) and Borax ($Na_2B_4O_7.10H_2O$ containing 11% boron) were used as the nutrient sources for S and B respectively. The purpose of the investigation was to study the pattern of release of these nutrients from these sources to the soil at periodic intervals to be taken as the indication of the availability of these nutrients to the crop at its different growth stages. The technical details of the incubation study are given below.

Design : 4^2 Completely Randomised Design

No. of replications : 2

Treatments :4 levels each of sulphur and boron

Levels of S	Levels of B
S_0 - 0 kg ha^{-1}	B_0 - 0 kg ha^{-1}
S_1 -7.5 kg ha^{-1}	B_1 - 2.5 kg ha^{-1}
S_2 - 15.0 kg ha^{-1}	B_2 - 5.0 kg ha^{-1}
S_3 - 30.0 kg ha^{-1}	B_3-7.5 kg ha

Treatment Combinations:16

Treatment Combination	Notation	Levels of Nutrients (kg ha^{-1})	
		S	B
T_1	S_0 B_0	0	0
T_2	S_0 B_1	0	2.5
T_3	S_0 B_2	0	5.0
T_4	S_0 B_3	0	7.5
T_5	S_1 B_0	7.5	0
T_6	S_1 B_1	7.5	2.5
T_7	S_1 B_2	7.5	5.0
T_8	S_1 B_3	7.5	7.5
T_9	S_2 B_0	15	0
T_{10}	S_2 B_1	15	2.5
T_{11}	S_2 B_2	15	5.0
T_{12}	S_2 B_3	15	7.5
T_{13}	S_3 B_0	30.0	0
T_{14}	S_3 B_1	30.0	2.5
T_{15}	S_3 B_2	30.0	5.0
T_{16}	S_3 B_3	30.0	7.5

The soil samples for incubation study were collected from plots permanently under sesame during summer at Onattukara Regional Agricultural Research Station, Kayamkulam. The collected samples were thoroughly mixed, air dried under shade and sieved through 2 mm sieve.

One kilogram each of soil was incubated at field capacity for fifty days in plastic containers and maintained at field capacity through out the period of incubation by replenishing the moisture lost by evaporation which was found out by calculating the weight difference. Calculated quantities of gypsum and borax to supply the required quantities of nutrients as per the treatment schedule were weighed and applied to the soil maintained at room temperature.

Sampling of the incubated soil for chemical analysis was carried out as per the following schedule fixing the stages of sampling to coincide with critical growth stages of sesame crop.

Stages of sampling	Critical growth stage of the crop
Stage I: 20 days after incubation	4-5 leaf stage
Stage II: 30 days after incubation	Branching stage
Stage III: 40days after incubation	Flowering stage
Stage IV: 50days after incubation	Pod formation stage

Samples were analysed for S and B content following standard analytical procedures as shown in Table1.

3.2 FIELD EXPERIMENTS

Two field experiments were conducted by raising two crops of sesame as lowland crop in paddy field at Onattukara Regional Agricultural Research Station, Kayamkulam. The two crops were raised during the period from 21-2-2007 to 12-05-2007 and from 22-1-2009 to 11-4-2009 respectively. Cultivation of the crops was done as per the POP recommendations (KAU, 2008).

3.2.1 Experimental Site

The field experiments during both the seasons were laid out in plot No.4 of E block of the farm attached ORARS, Kayamkulam. The area is located at 90 30' N latitude and 76^{0}20' East longitude at an altitude of 3.05m above mean sea level.

3.2.2 Soil

The soil belongs to Oxyaquic Quartzi Psamment subgroup. Important physico-chemical properties of the soil were estimated as per the standard procedures given in Table1.

3.2.3 Season

The first crop was grown from February to May 2007 and the second crop from January to April 2009. During both the seasons, the crops were grown as third crop in summer rice fallows. Weather parameters during entire cropping season were recorded from Meteorological Observatory attached to ORARS Farm, Kayamkulam and presented as weekly average in Appendix I.

3.2.4 Crop and Variety

The variety chosen for the study was Thilarani, a high yielding variety of sesame widely popular in Onattukara as third crop in summer rice fallows. It is a cross between Kayamkulam 1 and Thilak. This is a semi tall variety with resistance to major pests and diseases.

3.2.5 Planting Material

Seeds of Thilarani purchased from ORARS, Kayamkulam were used as planting material in both crops.

3.2.6 Manures and Fertilisers

Gypsum ($CaSO_4$ $2H_2O$) was used as S source and Borax ($Na_2B_4O_7$. 10 H_2O) as used as the B source and both were applied basally. Schedule of application of organic matter and other nutrients, N, P and K were uniform for all the treatments and as per POP (KAU, 2008) viz 5 t ha^{-1} and 30:15:30 kg ha^{-1} respectively. The N, P and K were applied as urea (46 % N), bone meal (21 % P_2O_5) and muriate of potash (60 % K_2O) respectively. The choice of bone meal as P source was to exclude the conventional P sources like rock phosphate and super phosphate which contain S in appreciable quantities.

3.2.7 Design and layout of experiment

The layout plan of the experimental field is presented in Fig. 1.

Design : 4^2 Factorial Randomized Block Design

No. of replications : 2

Plot Size : 5 x 4 sq.m

Spacing : 20 x 15cm

Total number of plots : 32

Treatments : 4 levels each of S and B

Levels of S	**Levels of B**
S_0 - 0 kg ha^{-1}	B_0 - 0 kg ha^{-1}
S_1 -7.5 kg ha^{-1}	B_1 - 2.5 kg ha^{-1}
S_2 - 15.0kg ha^{-1}	B_2 - 5.0kg ha^{-1}
S_3 - 30.0kg ha^{-1}	B_3-7.5kg ha

Treatment Combinations: 16

Treatment Combination	Notation	Levels of Nutrients(kg ha^{-1})	
		S	B
T_1	$S_0 B_0$	0	0
T_2	$S_0 B_1$	0	2.5
T_3	$S_0 B_2$	0	5.0
T_4	$S_0 B_3$	0	7.5
T_5	$S_1 B_0$	7.5	0
T_6	$S_1 B_1$	7.5	2.5
T_7	$S_1 B_2$	7.5	5.0
T_8	$S_1 B_3$	7.5	7.5
T_9	$S_2 B_0$	15	0
T_{10}	$S_2 B_1$	15	2.5
T_{11}	$S_2 B_2$	15	5.0
T_{12}	$S_2 B_3$	15	7.5
T_{13}	$S_3 B_0$	30.0	0
T_{14}	$S_3 B_1$	30.0	2.5
T_{15}	$S_3 B_2$	30.0	5.0
T_{16}	$S_3 B_3$	30.0	7.5

N

R1					R2			
T_4	T_{16}	T_{11}	T_{13}		T_{11}	T_1	T_{15}	T_5
T_{14}	T_3	T_8	T_2		T_7	T_{14}	T_2	T_8
T_9	T_7	T_{15}	T_6		T_3	T_{12}	T_{10}	T_4
T_5	T_{12}	T_{10}	T_1		T_{13}	T_6	T_{16}	T_9

Fig. 1. Layout plan of the experiment

3.2.8 Details of Cultivation

3.2.8.1 Sowing

The land was ploughed thoroughly using the power tiller twice and weeds and stubbles of the previous paddy crop were removed. Seeds were dibbled in lines at the rate of 3 seeds per hole at a spacing of 20 cm between rows and 15 cm between two dibblings. The land was again worked gently with wooden planks for the seeds to have a uniform covering of soil. Small wooden poles were used to demarcate the boundaries of the plots.

3.2.8.2 Manuring

The entire quantity of cattle manure was applied basally and incorporated into soil during last ploughing. Seventy five per cent of urea and whole of bone meal and muriate of potash were applied basally. Second dose of urea (25%) was given as foliar spray at three per cent concentration three weeks after dibbling.

3.2.8.3 Treatment application

As done for incubation study, gypsum and borax were used as sources of S and B respectively for the field experiments also. Required quantities of these chemicals to supply the nutrients as per the treatment schedule were weighed out, dissolved in water and applied seven days after dibbling the seeds. For uniform application, the chemicals were dissolved in water and applied at the rate of 10 litres per plot.

3.2.8.4 After cultivation

Light hoeing followed by raking were given two times during the cropping period. Thinning was done two weeks after sowing. Second dose of urea was given as foliar spray three weeks after sowing. Two hand weedings were also done before second dose of fertiliser application.

3.2.8.5 Irrigation

Summer showers were scanty during both crop periods and hence irrigations were given at the critical stages ie., 4-5 leaf stage, branching stage, flowering stage and pod formation stage.

3.2.8.6 Plant protection

The variety chosen was resistant to pests and diseases and hence plant protection measures were not required during the crop period.

3.2.8.7 Crop duration

Yellowing of capsules were taken as the index of maturity. The duration of the variety was found to be 81 days for the first crop and 80 days for the second crop.

3.2.8.8 Harvesting

Harvesting was done by pulling out the plants and cutting the root portions. The root portions were cut and the plants were stacked in bundles for three to four days for shedding the leaves. These were then spread in the sun and were beaten with sticks to break open the capsules. This was repeated for three days. The seeds from each plot were collected and kept separately. They were then winnowed and sundried and weighed for the estimation of the seed yield per plant and per plot.

3.2.9 Biometric Observations Recorded

For recording observations and sampling four stages of crop growth were identified in addition to harvest stage.

Stage I: 20 Days After Sowing	-	4-5 leaf stage
Stage II: 30 Days After Sowing	-	Branching stage
Stage III: 40 Days After Sowing	-	Flowering stage
Stage IV: 50 Days After Sowing	-	Pod formation stage

Five representative plants were selected at the sampling stages mentioned above for recording the biometric observations and their average was calculated for each parameter.

3.2.9.1 Height of the plant (cm)

Height of the plant was measured from the ground level to the growing tip of plants.

3.2.9.2 Number of branches Plant^{-1}

The number of both primary and secondary branches plant^{-1} were counted at the sampling stages.

3.2.9.3 Leaf area (cm^2)

The leaf area was estimated by graphical method. The outline of each leaf of a plant was plotted in a graph paper and the area was then calculated. The total leaf area of the plant was then computed by summing up the area of individual leaves.

3.2.9.4 Length of internodes (cm)

The internodal length of five observation plants was measured as the vertical distance between two adjacent leaf axils.

3.2.9.5 Root volume (ml)

Root volume was measured by noting the volume of water displaced by the root when immersed in a measuring cylinder containing known volume of water.

3.2.9.6 Root spread (cm)

The separate roots were placed on a hard surface. Root spread was measured as the lateral spread of the outermost root from the tap root.

3.2.10 Yield and yield attributes

The five representative plants selected for recording the shoot characters were used for recording yield and its attributes.

3.2.10.1 Days to first flowering

Number of days to reach first flowering were counted from the date of dibbling to the date at which first flowering in a plot was observed.

3.2.10.2 Days to fifty per cent flowering

Number of days to reach fifty per cent flowering was counted from the date of dibbling to the date on which flowering was noticed in nearly fifty per cent of the total population in a plot.

3.2.10.3 Number of capsules plant^{-1}

The total number of capsules borne by both primary and secondary branches of each observation plant were counted and the average value was worked out.

3.2.10.4 Seeds capsule^{-1}

The number of seeds from the dried capsules of the five observation plants were counted and the average was worked out.

3.2.10.5 Thousand seed weight (g)

After drying, the seeds were separated and the weight of thousand seeds were recorded separately.

3.2.10.6 Shelling percentage

The dry weight of seeds and pods were taken and their ratio was worked out as percentage.

$$\text{Shelling Percentage: } \frac{\text{Dry weight of seeds}}{\text{Dry weight of pods}} \times 100$$

3.2.10.7 Harvest Index

Grain and bhusa yields were recorded. The harvest index was found out by taking the ratio between grain and bhusa yield.

3.2.10.7 Seed yield plant^{-1} (g plant^{-1})

The total quantity of seeds from each observation plant were estimated as seed yield plant^{-1}.

3.2.10.8 Oil content (%)

Oil was estimated from known weight of the seeds adopting the solvent extraction process. The oil was extracted using hexane using a soxhelet apparatus and the content was expressed on percentage basis.

3.2.11 Quality parameters

The important quality parameters recorded include protein content of seed, oil content, oil constants like saponification value, acid value and iodine value, fractionation of oil for saturated and unsaturated fatty acids.

3.2.11.1 Seed protein content (%)

Seed protein content was worked out by multiplying seed nitrogen value by the factor 6.25 (Simpson *et al.*, 1965) where N was estimated by the Microkjeldhal digestion in sulphuric acid and distillation (Jackson, 1973).

3.2.11.2 Oil constants

3.2.11.2.1 Acid value

Acid value of the oil was estimated by dissolving a weighed quantity of the oil in alcohol and titrating this against the standard alkali using phenolphthalein as the indicator. Method as outlined by Paraquot and Hautfenne (1987) was followed.

3.2.11.2.2 Saponification value

Saponification value was estimated by refluxing a weighed quantity of the oil with a known excess of alcoholic potash. After complete saponification, the excess potash was determined by titration with standard hydrochloric acid . The method described by Paraquot and Hautfenne (1987) was followed.

3.2.11.2.3 Iodine value

The iodine value was estimated by treating a known weight of the oil with a known excess volume of Wij's solution which is a mixture of iodine and iodine trichloride in glacial acetic acid (Paraquot and Hautfenne, 1987).

3.2.11.3 Fractionation of fatty acids

Oil was extracted using the soxhelet apparatus. Fatty acid composition of the oil was estimated from the methyl ester of the fatty acid obtained by treatment with methanolic sulphuric acid mixture. The methyl esters were analysed in Hewlett Packard 5890 Series II Gas Chromatography. The column used was D.B23 capillary column (30 m X 0.320 mm X 0.25 µm). The conditions were programmed at 100- 180°C @ 5°minute^{-1}.

3.2.12 Chemical analysis

3.2.12.1 Plant and grain analysis

For studying the effect of the S and B on the growth, yield and quality of sesame, the plants were grown to maturity and harvested and the plant and grain samples were collected.

For standardizing the stage and index part for foliar diagnosis for the nutrients, destructive sampling of the plants was resorted. For this purpose four plants were maintained in each plot and they were sampled for chemical analysis segregating into different parts at different stages of the crop as shown below.

Plant parts sampled

1. Lamina
2. Petiole
3. Midrib
4. Internode

Stages of sampling

1. 4-5 leaf stage (20 DAS)

2. Branching (30 DAS)
3. Flowering stage (40 DAS)
4. Pod formation stage (50 DAS)

Plant samples were collected at four sampling stages ie., 20, 30, 40, 50 DAS and at the time of harvest. The samples were oven dried at 70°C and powdered and used for the estimation of S and B at the four sampling stages and for N, P, K, Ca, Mg, S, Fe, Mn, Cu and Zn at the time of harvest. Standard procedures adopted are given in Table 2.

3.2.12.2 Uptake of nutrients (Kg ha^{-1})

Uptake of nutrients by grain and bhusa were calculated by multiplying the nutrient concentration with corresponding dry weight. Total nutrient uptake by plant was calculated by adding the nutrient uptake by grain and bhusa.

3.2.12.3 Soil analysis

Soil samples were collected before sowing at the four sampling stages and also at the time of harvest of the crop. The samples were air dried and passed through 2 mm sieve. The samples collected before planting and after the harvest of each crop, the samples were analysed for the estimation of organic C, N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, pH and EC using standard procedures as given in Table 3. At the four sampling stages, the samples were analysed for S and B.

3.2.13 Nutrient Efficiency Terminologies

The primary data generated by the above procedures were utilized to compute the following nutrient efficiency parameters as described below.

3.2.13.1 Sulphur use efficiency (%)

Sulphur Use Efficiency was calculated by the formula:

$$\frac{\text{Grain yield in treated plot- Grain yield in control}}{\text{Rate of S applied (kg ha}^{-1}\text{)}} \times 100$$

3.2.13.2 Boron use efficiency (%)

Boron use efficiency is calculated by the formula:

$$\frac{\text{Grain yield in treated plot- Grain yield in control}}{\text{Rate of B applied (kg ha}^{-1}\text{)}} \times 100$$

3.2.13.3 Apparent sulphur recovery

$$\frac{\text{S uptake in treated plot} - \text{S uptake in control}}{\text{S applied (kg ha}^{-1}\text{)}} \times 100$$

3.2.13.4 Apparent boron recovery

$$\frac{\text{B uptake in treated plot} - \text{B uptake in control}}{\text{B applied (kg ha}^{-1}\text{)}} \times 100$$

3.2.14 Economic Analysis

The benefit- cost ratio (BCR) was worked out taking into consideration of all aspects of cost of cultivation and income generated by the crop pertinent to each treatment.

3.2.15 Statistical Analysis

The data generated out of the laboratory and field investigations were scrutinized statistically to aid in the interpretation of the results.

Analysis of variance applicable to factorial randomized block design was done to brig out the effect of S and B on the growth, yield and quality characters o sesame (Cochran and Cox, 1963).

For indexing the plant part for foliar diagnosis, correlation studies (Snedocor and Cochran, 1967) and for fixing the critical nutrient levels for maximum yield scatter diagram technique (Cate and Nelson, 1965) were adopted.

Table 1. Analytical methods followed in plant analysis

Sl. No.	Element	Method	Reference
1	N	Microkjeldhal digestion in sulphuric acid and distillation	Jackson (1973)
2	P	Nitric-perchloric acid digestion (9 : 3) and colorimetery making use of vanado molybdo phosphoric yellow colour method	Jackson (1973)
3	K	Nitric – perchloric acid (9 : 3) digestion and flame photometry	Jackson (1973)
4	Ca	Nitric – perchloric acid (9 :3) digestion and versenate titration with standard EDTA	Tandon (1993)
5	Mg	Nitric – perchloric acid (9 : 3) digestion and versenate titration with standard EDTA	Tandon (1993)
6	S	Nitric – perchloric acid (9 : 3) digestion.and turbidemetry	Tabatabai and Bremner (1970)
7	Fe, Mn, Cu, Zn	Nitric – perchloric acid (9 : 3) digestion and Atomic Absorption spectrophotometry	Lindsay and Norvell (1978)
8	B	Azomethine –H colorimetric method	Bingham (1982)

Table 2. Analytical methods followed in soil analysis

Sl. No.	Parameter	Method	Reference
1	Mechanical composition	International Pipette Method	Piper (1967)
2	Particle density	Pycnometer method	Black *et al.* (1965)
3	Bulk density	Undisturbed core sample	Black *et al.* (1965)
4	Water holding capacity	Undisturbed core sample	Black *et al.* (1965)
5	Hydraulic conductivity	Undisturbed core sample	Black *et al.* (1965)
6	pH	Potentiometry	Jackson (1973)
7	Electrical Conductivity	Conductivity meter	Jackson (1973)
8	Organic carbon	Walkley and Black Chromic acid wet digestion method	Walkley and Black (1934)
9	Available P	Bray extraction and photo electric colorimetry	Jackson (1973)
10	Available K	Flame photometry	Pratt (1965)
11	Available S	Turbidimetry	Chesnin and Yien (1951)
12	Exchangeable Ca and Mg	Neutral normal ammonium acetate extraction and titration with EDTA (Versenate titration)	Hesse (1971)
13	Fe, Mn, Cu, Zn	Extraction using DTPA and read in Atomic Absorption Spectrophotometer	Lindsay and Norvell (1978)
14	B	Hot water extraction method	Berger and Truog (1939)

RESULTS

4. RESULTS

Investigations were carried out at Onattukara Regional Agricultural Research Station, Kayamkulam and at College of Agriculture, Vellayani to study the effect of S and B nutrition on the growth and yield of sesame and to standardize the foliar diagnosis of these elements. The investigations consisted of an incubation study and two field experiments. The important physico chemical characteristics of the soil are depicted in Table 3. The results of the study are presented in this section.

4.1 INCUBATION STUDY

The incubation study was conducted to understand the releasing pattern of S and B from their sources, gypsum and borax respectively in a Typic Quartzi Psamment soil. The effect of levels of S and B and the interaction effect of these nutrients at various stages of incubation study are presented in Tables 4 and 5 respectively.

4.1.1 Available sulphur (Table 4)

4.1.1.1 20th DOI

It is obvious from the data presented in Table 4 that application of treatments had a significant effect on the release of S at the 20th DOI. The maximum value of 44.76 kg ha^{-1} which was significantly higher than other treatments was shown by T_{16} (S_3B_3), the treatment which received S and B at the highest level of 30 kg ha^{-1} and 7.5 kg ha^{-1} respectively and this trend was repeated throughout the period of incubation. This was followed by T_{15} (S_3B_2) which received S@30 kg ha^{-1} and B@ 5.0 kg ha^{-1}. The lowest value of 12.71 kg ha^{-1}was observed in T_1 (S_0B_0) which received no S or B. All the treatment combinations which received S at the highest dose showed superior values in the order of increasing levels of B applied.

Table 3. Physico-chemical properties of the soil at the experiment site

Sl. No.	Parameter	Content
A.	**Mechanical composition**	
1	Coarse sand	68.55%
2	Fine sand	17.00 %
3	Silt	5.55 %
4	Clay	8.35%
5	Texture	Loamy Sand
B.	**Physical properties**	
1	Particle density	2.43 Mg m^{-3}
2	Bulk density	1.58 Mg m^{-3}
3	Water holding capacity	23.00 %
C	**Chemical properties**	
1	pH	5.10
2	EC	0.30 dSm^{-1}
3	Organic carbon	0.31 per cent
4	Available phosphorus	6.50 kg ha^{-1}
5	Available potassium	62.00 kg ha^{-1}
6	Exchangeable Calcium	0.48 cmol kg^{-1}
7	Exchangeable Magnesium	0.034 cmol kg^{-1}
8	Available sulphur	10.20 kg ha^{-1}
9	Available boron	0.18 ppm
	DTPA extractable micronutrients	
12	Iron	8.20 ppm
13	Manganese	1.62 ppm
14	Copper	0.30
15	Zinc	Traces
16	CEC	3.2 cmol kg^{-1}

As regard to the main effects of S and B, the levels of these nutrients were significant for the content of available S in the soil throughout the period of incubation. All the treatments were significantly lower than S_3 (30.0 kg S ha^{-1}) which recorded a value of 40.03 kg ha^{-1}. The lowest value of 14.86 kg ha^{-1} was shown by S_0 (0 kg S ha^{-1}). Among the levels of B, B_3 (7.5 kg B ha^{-1}) recorded the highest value of 29.82 kg ha^{-1} followed by B_2 (5.0 kg B ha^{-1}). The lowest value (25.21 kg ha^{-1}) was shown by B_1 (2.5 kg B ha^{-1}).

4.1.1.2 30th DOI

All the treatments showed a gradual increasing trend by the 30th DOI and among the four stages of sampling, this period recorded the maximum available S content. Among the various treatments, the highest value of 48.21 kg ha^{-1} was recorded by T_{16} (S_3B_3) followed by T_{15} (S_3B_2). The lowest value of 19.87 kg ha^{-1} was shown by T_1 (S_0B_0).

The individual effects of S and B were also significant with regard to the parameter. S_3 (30.0 kg S ha^{-1}) was the significantly superior level of S followed by S_2 (15.0 kg S ha^{-1}) and recorded a value of 41.73 kg ha^{-1}. All the levels were significantly higher than S_0 (0 kg S ha^{-1}) which showed a value of 22.84 kg ha^{-1}. Among the levels of B, B_3 (7.5 kg B ha^{-1}) recorded the highest value of 32.96 kg ha^{-1} and was on par with B_2 (5.0 kg B ha^{-1}). The lowest value of 26.87 kg ha^{-1} was recorded by B_0 (0 kg B ha^{-1}).

4.1.1.3 40th DOI

From 40th DOI onwards, a decrease in the available S was noticed. At the 40th DOI, the interaction between different levels of S and B was also found to be significant and the highest value of 33.26 kg ha^{-1} was recorded by T_{16} (S_3B_3) followed by T_{15} (S_3B_2). The lowest value of 12.98 kg ha^{-1} was recorded by T_1 (S_0B_0) preceded by T_2 (S_0B_1).

Critical evaluation of the individual effects showed that S_3 (30.0 kg S ha^{-1}) was the significantly superior S level which recorded a value of

Table 4. Available S content of soil at different stages of incubation (kg ha^{-1})

Treatments	20th DOI	30th DOI	40th DOI	50th DOI
$S_0 B_0$	12.71	19.87	12.98	5.58
$S_0 B_1$	16.23	22.42	15.42	6.70
$S_0 B_2$	13.50	24.69	17.21	6.55
$S_0 B_3$	17.00	24.39	19.73	7.09
$S_1 B_0$	21.50	25.17	21.89	7.54
$S_1 B_1$	21.03	25.40	21.73	7.37
$S_1 B_2$	22.50	26.63	21.83	8.98
$S_1 B_3$	23.00	26.34	25.42	8.21
$S_2 B_0$	31.50	27.70	26.39	8.42
$S_2 B_1$	29.82	28.23	26.68	10.18
$S_2 B_2$	34.00	30.84	27.29	11.56
$S_2 B_3$	34.50	32.89	28.36	12.68
$S_3 B_0$	36.50	34.76	29.32	17.50
$S_3 B_1$	36.50	38.97	30.20	20.00
$S_3 B_2$	42.35	45.00	31.94	21.50
$S_3 B_3$	44.76	48.21	33.26	23.50
S_0	14.86	22.84	16.33	6.48
S_1	22.06	25.88	22.72	8.02
S_2	32.46	29.92	27.17	10.71
S_3	40.03	41.73	31.18	20.63
B_0	25.56	26.87	22.64	9.76
B_1	25.21	28.75	23.51	11.06
B_2	28.77	31.79	24.57	12.15
B_3	29.82	32.96	26.69	12.87
F-S	134.59**	38.87**	41.66**	124.82**
F-B	5.76**	4.39*	4.13*	5.67**
F-SXB	2.75*	2.78*	3.26*	1.87^{NS}
CD - S	2.875	3.98	2.96	1.71
CD - B.	2.875	3.98	2.96	1.71
CD - S.B.	5.750	7.97	5.91	-

31.18 kg ha^{-1}. The lowest value of 16.33 kg ha^{-1} was recorded by S_0 (0 kg S ha^{-1}). Among the levels of B, B_3 (7.5 kg B ha^{-1}) was the superior treatment which recorded a value of 26.69 kg ha^{-1} and was on par with B_2 (5.0 kg B ha^{-1}). The lowest value of 22.64 kg ha^{-1} was shown by B_0 (0 kg B ha^{-1}).

4.1.1.4 50th DOI

At the last stage of incubation (50th DOI), all the treatments recorded the lowest value compared to the other three stages. The treatments which received S@30 kg ha^{-1} recorded comparatively higher values than the other combinations. T_{16} (S_3B_3) registered the highest and superior value of 23.50 kg ha^{-1}. Here also the lowest value of 5.58 kg ha^{-1} was recorded by T_1 (S_0B_0).

Considering the individual effects, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were significantly superior to the other levels and recorded the values of 20.63 kg ha^{-1} and 12.87 kg ha^{-1} respectively. The lowest values of 6.48 kg ha^{-1} and 9.76 kg ha^{-1} were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.1.2 Available (Hot Water Soluble) boron (Table 5)

Statistical analysis revealed that the content of hot water extractable B in the soil was significantly influenced by the application of different combinations of S and B at all stages of incubation. The treatment effects were highly significant.

4.1.2.1 20th DOI

At the 20th DOI, the highest value of 2.05 ppm among the different treatment combinations was recorded by T_{12} (S_2B_3) which was significantly superior to the other treatments followed by T_{11} (S_2B_2) and T_{16} (S_3B_3) which were on par. The lowest value of 0.22 ppm was recorded by T_1 (S_0B_0) preceded by T_6 (S_1B_1) and T_2 (S_0B_1) and they were on par. It had been statistically observed that as the levels of B increased an

Table 5. Available B content of soil at different stages of incubation study (ppm)

Treatments	20^{th} DOI	30^{th} DOI	40^{th} DOI	50^{th}DOI
S_0 B_0	0.220	0.270	0.180	0.130
S_0 B_1	0.350	0.180	0.201	0.160
S_0 B_2	0.390	0.330	0.210	0.170
S_0 B_3	0.680	0.670	0.280	0.180
S_1 B_0	0.350	0.340	0.370	0.240
S_1 B_1	0.340	0.390	0.410	0.240
S_1 B_2	0.530	0.790	0.440	0.300
S_1 B_3	0.860	0.890	0.480	0.350
S_2 B_0	1.160	0.560	0.690	0.210
S_2 B_1	1.230	0.720	0.680	0.360
S_2 B_2	1.780	1.050	0.700	0.530
S_2 B_3	2.050	2.450	0.760	0.640
S_3 B_0	0.490	0.360	0.730	0.440
S_3 B_1	0.930	0.500	0.820	0.650
S_3 B_2	1.420	0.710	1.070	0.660
S_3 B_3	1.480	1.440	1.590	0.825
S_0	0.411	0.363	0.219	0.161
S_1	0.520	0.603	0.424	0.282
S_2	1.550	1.200	0.704	0.435
S_3	1.080	0.752	1.050	0.645
B_0	0.557	0.386	0.492	0.258
B_1	0.711	0.446	0.529	0.352
B_2	1.030	0.720	0.603	0.416
B_3	1.270	1.370	0.775	0.498
F-S	110.42**	30.25**	117.04**	52.51**
F-B	39.85**	49.13**	14.19**	12.42**
F-SXB	2.95*	6.22**	6.69**	3.19*
CD - S	0.151	0.192	0.100	0.0863
CD - B.	0.151	0.192	0.100	0.0863
CD - S.B.	0.303	0.384	0.200	0.173

increasing trend for the available B content was recorded. The combination of B and S at higher levels recorded significantly superior values.

Regarding the individual effects of different levels of S and B, S_2 (15.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded significantly superior values of 1.55 ppm and 1.27 ppm respectively compared to the other levels. The lowest values of 0.411 ppm and 0.557 ppm were shown by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.1.2.2 **30th DOI**

At the 30th DOI, T_{12} (S_2B_3) was significantly superior to other combinations of S and B. The values ranged from 0.177 ppm (T_2-S_0B_1) to 2.45 ppm (T_{12}-S_2B_3). The lowest value recorded by T_2 (S_0B_1) was on par with T_1 (S_0B_0).

Regarding the main effects of S and B, S_2 (15.0 kg S ha^{-1}) was the significantly superior level of S followed by S_3 (30.0 kg S ha^{-1}) and S_1. Among the B levels, B_3 (7.5 kg B ha^{-1}) recorded the highest value followed by the next higher value B_2 (5.0 kg B ha^{-1}). S_2 (15.0 kg ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the values of 1.20 ppm and 1.37 ppm respectively.

4.1.2.3 **40th DOI**

At the 40th DOI, as in the case of S, the available B content also showed a decreasing trend. T_{16} (S_3B_3) recorded the significantly superior value of 1.59 ppm. The lowest value of 0.184 ppm was shown by T_1 (S_0B_0).

S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the significantly superior levels of S and B and recorded the values of 1.05 ppm and 0.775 ppm respectively. They were followed by their next levels such as S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}). S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) recorded the lowest values of 0.219 ppm and 0.492 ppm respectively.

4.1.2.4 50^{th} DOI

Critical examination of the data revealed that by the 50^{th} DOI, the interaction effect of S and B became more pronounced such that treatment combinations with these nutrients at the highest levels showed comparatively higher values than that of other combinations. All the treatment combinations recorded comparatively lower values. As in the case with the other stages of incubation, T_{16} (S_3B_3) recorded significantly the highest value followed by T_{15} (S_3B_2) and T_{14} (S_3B_1). The lowest values were recorded by T_1 (S_0B_0) and T_2 (S_0B_1) and were on par. The values ranged between 0.130 ppm and 0.830 ppm.

Among the different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) showed highest values which were 0.645 ppm and 0.498 ppm respectively. This was followed by S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}).

4.2 FIELD EXPERIMENTS

4.2.1 Effect of treatments on biometric characteristics of sesame at the different sampling stages

For studying the effect of application of S and B and their interaction on the growth characters of sesame, the attributes like height of plant, number of primary and secondary branches $plant^{-1}$, length of internodes, fresh weight of plant, leaf area $plant^{-1}$, and root characters like root spread and root volume were considered. The sampling stages fixed were 20, 30, 40 and 50 DAS which coincided with 4-5 leaf stage, branching, flowering and pod formation stage respectively and at harvest.

4.2.1.1 20 DAS

The data on the biometric and root characters of sesame at 20 DAS are shown in Table 6. Perusal of the data revealed that no parameters except the root spread showed significant effect due to the application of different levels of S and B.

4.2.1.1.1 Height of plant

It had been found that there was no significant effect for the interaction between different levels of S and B on the height of the plant. However the highest value of 7.50 cm among the different treatments was shown by T_8 (S_1B_3) followed by T_7 (S_1B_2) and the lowest value (4.70 cm) was recorded by T_{14} (S_3B_1).

The individual effects of S and B also did not register any significant effect on this parameter. Among the different levels of S, S_1 (7.5 kg S ha^{-1}) recorded the highest value of 6.53 cm and the lowest value of 5.29 cm was shown by S_3. The different levels of B also did not have any significant effect. B_0 (0 kg B ha^{-1}) and B_2 (5.0 kg B ha^{-1}) recorded the lowest and highest values of 5.75 cm and 6.08 cm respectively.

4.2.1.1.2 Leaf area plant^{-1}

It can be observed from the data that the leaf area plant^{-1} was significantly influenced by the interaction between different levels of S and B. The highest value of 62.60 cm^2 which was significantly superior to the others was recorded by T_{14} (S_3B_1). The lowest value of 13.87 cm^2 was shown by T_1 (S_0B_0).

The individual effects of different levels of S and B also registered significant effect on the leaf area plant^{-1}. S_3 (30.0 kg S ha^{-1}) showed the highest value of 38.92 cm^2 and was on par with S_2. The lowest value of 26.85 cm^2 was shown by S_0 (0 kg S ha^{-1}). Among the different levels of B, B_1 (2.5 kg B ha^{-1}) was the significantly superior level which recorded a value of 41.91 cm^2. The lowest value of 27.26 cm^2 was shown by B_0 (0 kg B ha^{-1}).

Table 6. Biometric characters of Sesame at 20 DAS

Treatments	Height (cm)	Fresh Weight (g plant^{-1})	Root Spread (cm)	Root Volume (ml)	Leaf area (cm^2)
$S_0 B_0$	5.35	0.515	2.00	0.1750	13.87
$S_0 B_1$	6.00	1.11	6.25	0.5000	26.25
$S_0 B_2$	5.90	1.02	8.45	0.5500	36.03
$S_0 B_3$	5.30	0.635	5.00	0.3500	31.25
$S_1 B_0$	6.20	0.655	3.30	0.3000	33.00
$S_1 B_1$	5.90	0.645	5.00	0.2250	36.25
$S_1 B_2$	6.50	0.625	6.20	0.1500	34.60
$S_1 B_3$	7.50	0.785	7.35	0.2500	31.90
$S_2 B_0$	5.75	0.720	5.50	0.2250	26.40
$S_2 B_1$	6.40	1.080	3.10	0.6000	42.53
$S_2 B_2$	6.40	0.845	2.60	0.3750	42.09
$S_2 B_3$	5.75	1.070	3.10	0.6250	34.90
$S_3 B_0$	5.70	1.030	5.40	0.7500	35.76
$S_3 B_1$	4.70	0.800	8.20	0.5000	62.60
$S_3 B_2$	5.50	0.735	4.60	0.6250	28.50
$S_3 B_3$	5.25	0.940	5.00	0.3750	28.80
S_0	5.64	0.819	5.43	0.394	26.85
S_1	6.53	0.678	5.46	0.231	33.94
S_2	6.08	0.929	3.58	0.456	36.48
S_3	5.29	0.876	5.80	0.563	38.92
B_0	5.75	0.730	4.05	0.363	27.26
B_1	5.75	0.908	5.64	0.456	41.91
B_2	6.08	0.806	5.46	0.425	35.30
B_3	5.95	0.857	5.11	0.400	31.71
F-S	2.96^{NS}	2.56^{NS}	3.35*	1.42^{NS}	10.41 **
F-B	0.263^{NS}	1.26^{NS}	1.67^{NS}	0.11^{NS}	14.69**
F-S.B	0.719^{NS}	2.08^{NS}	3.47*	0.547^{NS}	8.28**
CD - S	-	0.204	1.657	-	4.867
CD - B.	-	0.204	1.657	-	4.867
CD - S.B	-	0.408	3.314	-	9.734

4.2.1.1 .3 Fresh weight plant $^{-1}$

The perusal of the data revealed that no significant effect was registered by the interaction of different levels of S and B. However the highest value of 1.110 g plant $^{-1}$ was recorded by T_2 (S_0B_1) followed by T_{10} (S_2B_1). The lowest value of 0.515 g plant $^{-1}$ was recorded by T_1 (S_0B_0).

Among the different levels of S and B, S_2 (15.0 kg S ha^{-1}) recorded the highest value of 0.929 g plant^{-1}and the lowest value of 0.678 g plant^{-1}was recorded by S_1. B_1 (2.5 kg B ha^{-1}) recorded the highest value of 0.908 g plant^{-1}and the lowest value of 0.730 g plant^{-1}was shown by B_0 (0 kg B ha^{-1}).

4.2.1.1 .4 Root spread

Statistical analysis of the data revealed that the interaction of different levels of S and B had significant effect on the root spread at 20DAS. The highest value of 8.45 cm was shown by T_3 (S_0B_2) and was on par with T_{14} (S_3B_1) and T_8 (S_1B_3). The lowest value of 2.00 cm was recorded by T_1 (S_0B_0).

It has been found that the different levels of S and B applied, individually had also significant effect on the parameter. The highest values of 5.80 cm and 5.64 were recorded by S_3 (30.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively. The lowest values of 3.58 cm and 4.05 cm were recorded by S_2 (15 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.1.1 .5 Root volume

The data presented in Table 6 shows that the interaction between different levels of S and B had no significant effect on the root volume at 20 DAS. The values ranged between 0.175 ml and 0.750 ml recorded by T_1 (S_0B_0) and T_{13} (S_3B_0) respectively.

Among the different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) recorded the highest values of 0.563 ml and 0.456 ml. The lowest values were 0.231 ml and 0.363 ml recorded by S_1 (15.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.1.2 30 DAS (Table 7)

4.2.1.2 .1 Height of plant

Critical evaluation of the data shows the significant influence of different levels of S and B and their interaction on the height of the plant at 30 DAS. The highest value of 24.80 cm was shown by T_{10} (S_2B_1) which was on par with T_6 (S_1B_1). The lowest value of 19.20 cm was recorded by T_1 (S_0B_0).

The different levels of S and B individually had no significant effect on the height of the plant. The highest values of 22.76 cm and 23.12 cm were recorded by S_2 (15.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively. The lowest values recorded were 21.73 cm and 21.15 cm shown by S_0 (0 kg S ha^{-1}) and B_0 (0 B kg ha^{-1}) respectively.

4.2.1.2 .2 Length of internodes

Statistical analysis of the data showed that the different treatments tried could not produce any significant effect on the length of internodes at 30DAS. However, among the interaction between the different levels of S and B, it had been observed that the longest internode was recorded by T_{16} (8.68 cm) and the shortest (4.88 cm) being shown by T_9 (S_2B_0).

As for the individual effects, S_3 (30.0 kg ha^{-1}) and B_1 (2.5 kg ha^{-1}) recorded the highest values of 7.66 cm and 7.53 cm respectively. The lowest values of 6.59 cm and 6.34 cm were indicated by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.1.2 .3 No. of branches plant^{-1}

4.2.1.2 .3.1 No. of primary branches plant^{-1}

The data presented in Table 7 shows that the application of different levels of S and their interaction with B had significant effect on the number of primary branches $plant^{-1}$ at 30 DAS. Among the interaction effect, the values ranged from

Table 7. Biometric characters of Sesame at 30 DAS

Treatments	Height (cm)	Fresh weight (g plant^{-1})	No. of branches		Root Characters		Length of internodes (cm)	Leaf area (cm^2)
			Primary	Secondary	Root Spread(cm)	Root volume(ml)		
$S_0 B_0$	19.20	11.22	2.60	7.00	5.50	1.50	6.98	52.50
$S_0 B_1$	22.16	13.11	3.10	7.50	5.00	1.50	7.98	112.30
$S_0 B_2$	22.84	14.99	3.40	4.80	6.25	1.50	7.38	142.50
$S_0 B_3$	22.93	8.41	4.00	6.50	12.25	1.00	5.30	136.50
$S_1 B_0$	22.41	13.10	4.3000	7.10	15.25	3.00	6.88	138.00
$S_1 B_1$	23.95	11.99	4.20	5.58	9.00	1.50	6.38	143.00
$S_1 B_2$	20.86	12.71	4.00	6.60	8.00	1.50	6.53	126.00
$S_1 B_3$	23.67	16.78	4.75	7.60	6.00	2.00	8.13	138.00
$S_2 B_0$	21.79	14.71	4.90	5.30	6.75	1.50	4.88	112.00
$S_2 B_1$	24.8	17.03	3.37	6.60	8.30	2.00	7.75	160.00
$S_2 B_2$	22.43	19.00	4.00	7.00	8.00	2.00	6.50	165.00
$S_2 B_3$	22.02	13.49	3.30	5.50	12.25	1.00	7.23	145.00
$S_3 B_0$	21.21	9.76	3.40	5.7500	12.00	1.25	6.63	130.00
$S_3 B_1$	21.56	24.91	4.70	5.80	15.00	1.25	8.00	193.40
$S_3 B_2$	22.64	12.82	4.10	7.50	14.25	1.00	7.35	152.10
$S_3 B_3$	21.49	17.75	4.30	8.00	21.00	1.75	8.68	148.20
S_0	21.73	11.93	3.28	6.10	7.25	1.31	6.59	110.95
S_1	21.73	16.60	3.89	6.72	9.56	1.38	6.98	136.25
S_2	22.76	16.06	4.31	6.45	8.83	1.63	6.91	145.5
S_3	22.72	13.35	4.13	6.76	15.56	2.00	7.66	155.93
B_0	21.15	13.81	3.80	6.29	9.13	1.44	6.34	108.13
B_1	23.12	15.15	3.84	6.38	9.33	1.56	7.53	152.18
B_2	22.19	14.88	3.88	6.48	9.88	1.50	6.94	146.40
B_3	22.53	14.11	4.09	6.90	12.88	1.81	7.33	141.93
F	8.77**	3.80*	9.184**	0.4917^{NS}	158.47**	1.82^{NS}	0.799^{NS}	8.34**
F	18.28**	3.31*	0.7394^{NS}	0.3926^{NS}	36.48**	0.50^{NS}	1.07^{NS}	12.10**
F	2.90*	3.77**	4.60**	1.70^{NS}	35.46**	1.22^{NS}	1.0363^{NS}	6.86**
CD(S)	1.837	4.733	0.621	-	1.204	-	2.109	22.451
CD(B)	1.837	4.733	-	-	1.204	-	2.109	22.451
CD(SxB)	3.674	9.465	1.242	-	2.409	-	4.219	44.902

2.60 and 4.90 recorded by T_1 (S_0B_0) and T_9 (S_2B_0) respectively. These were on par with T_2 (S_0B_1) and T_8 (S_1B_3) respectively.

The different levels of S alone had significant effect on the number of primary branches plant. The highest value of 4.31 was recorded by S_2 (15.0 kg S ha^{-1}) and was on par with S_3 (30.0 kg S ha^{-1}). The lowest value of 3.28 was recorded by S_0 (0 kg S ha^{-1}). The different levels of B applied had no significant effect on this parameter. The values ranged between 3.80 and 4.09 recorded by B_0 (0 kg B ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively.

4.2.1.2 .3.2 No. of secondary branches plant^{-1}

Perusal of the data revealed that the interaction between different levels of S and B and their individual effects were not significant with regard to the number of secondary branches plant^{-1}.

Among the interaction effects, the highest number recorded was 8.0 shown by T_{16} (S_3B_3) and the lowest number of 4.80 by T_3 (S_0B_2).

Among the different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 6.76 and 6.90 respectively. The lowest values recorded were 6.10 and 6.29 recorded by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.1.2 .4 Leaf area plant^{-1}

The critical evaluation of the data on the leaf area plant^{-1} revealed that the interaction between different levels of S and B registered significant effect. The highest value of 193.40 cm^2 was recorded by T_{14} (S_3B_1) and was on par with T_{11}. The lowest value of 52.50 cm^2 was shown by T_1 (S_0B_0). All the treatments showed significantly superior values compared to it.

As regard to the main effects of different levels of S and B, significant effect was registered for both the nutrients. S_3 (30.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) recorded the highest values of 155.93 cm^2 and 152.18 cm^2 which were on par with S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively. The lowest values of

110.95 cm^2 and 108.13 cm^2 were shown by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.1.2 .5 Fresh weight plant^{-1}

Perusal of the data shows the significant effect of interaction between different levels of S and B. The highest value of 24.91 g plant^{-1} was recorded by T_{14} (S_3B_1) followed by T_{11} (S_2B_2) which were on par with each other. The lowest value of 8.41 g plant^{-1} was recorded by T_4 (S_0B_3).

Statistical analysis of the data revealed that the individual effects of different levels of S and B was also significant with regard to the fresh weight of the plant at 30 DAS. S_1 (7.5 kg S ha^{-1}) and B_1 (2.5 kg ha^{-1}) recorded the highest values of 16.60 g plant^{-1} and 15.15 g plant^{-1} respectively. The lowest values recorded were 11.93 g plant^{-1} and 13.81 g plant^{-1}by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.1.2 .6 Root spread

Perusal of the data revealed that the interaction of different levels of S and B and their individual effects had high significance on the root spread of sesame at 30DAS. Coming to the interaction between the different levels of the nutrient, T_{16} (S_3B_3) recorded the highest value of 21 cm which was significantly superior to the other treatment combinations. The lowest value of 5 cm was recorded by T_2 (S_0B_1) and was on par with T_1 (S_0B_0).

Among the different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest value of 15 cm and 12 cm respectively and were significantly superior to other levels. The lowest values recorded were 7.25 cm and 9.12 cm respectively being shown by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.1.2 .7 Root volume

It had been found that the application of S and B could not produce any significant effect on the root volume at 30 DAS. The interaction effect showed that the values ranged between 1.00 ml and 3.00 ml being recorded by T_4 (S_0B_3) and T_5 (S_1B_0) respectively.

Application of different levels of S and B individually also did not register any significant effect. The highest values of 2.00 ml and 1.81 ml were recorded by S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively. The lowest values produced by the two nutrients were 1.31 ml and 1.44 ml as shown by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.1.3 40 DAS (Table 8)

4.2.1.3 .1 Height of plant

Perusal of the data revealed that interaction of different levels of S and B had significant effect on the height of the plant. The maximum height of 44.67 cm was shown by T_{16} (S_3B_3) followed by T_{11} (S_2B_2) and were on par with each other. The lowest value 33.10 was produced by T_1 (S_0B_0).

The individual effects of S and B were also significant with regard to the parameter. Among the different levels of S and B, S_2 (15.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) recorded the maximum values of 41.75 cm and 39.85 cm. The lowest value was shown by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) as 37.71 cm and 38.41 cm respectively.

4.2.1.3 .2 Length of internodes

It had been observed that the length of internodes at 40 DAS was not significantly influenced by the application of different levels of S and B. Among the interaction effects, the values ranged between 5.88 cm and 9.55 cm recorded by T_1 (S_0B_0) and T_{10} (S_2B_1) respectively.

Coming to the individual effects of these nutrients, S_3 (30.0 kg S ha^{-1}) and B_1 (2.5 B kg ha^{-1}) recorded the highest values of 9.17 cm and 8.77 cm respectively. The

Table 8. Biometric characters of Sesame at 40 DAS

Treatments	Height (cm)	Fresh weight (g)	No. of branches		Root Characters		Length of internodes (cm)	Leaf Area (cm^2)
			Primary	Secondary	Root Spread (cm)	Root volume (ml)		
$S_0 B_0$	33.10	19.01	3.30	3.90	5.30	3.00	5.88	123.750
$S_0 B_1$	40.58	20.29	3.50	4.00	8.35	2.50	8.38	286.58
$S_0 B_2$	37.57	14.68	2.80	2.80	10.05	1.50	7.53	305.00
$S_0 B_3$	37.09	13.74	4.40	3.30	6.95	1.50	6.45	328.75
$S_1 B_0$	38.18	29.73	5.30	4.00	7.40	3.50	8.95	351.00
$S_1 B_1$	41.73	23.49	4.70	4.20	5.50	1.50	8.77	385.50
$S_1 B_2$	37.83	9.62	6.10	3.80	5.50	1.500	9.45	405.20
$S_1 B_3$	35.68	22.58	3.70	3.30	6.00	1.50	9.50	434.16
$S_2 B_0$	41.97	22.41	4.50	5.50	8.70	3.00	8.60	440.30
$S_2 B_1$	39.51	19.82	3.30	2.90	7.10	2.50	9.55	454.50
$S_2 B_2$	43.07	42.23	5.60	4.20	6.90	3.00	8.75	458.28
$S_2 B_3$	42.43	31.96	4.10	3.90	6.35	3.00	8.35	495.00
$S_3 B_0$	37.79	23.11	3.20	3.90	6.60	4.00	8.78	512.25
$S_3 B_1$	37.57	20.10	4.10	3.80	9.40	2.50	8.08	522.75
$S_3 B_2$	38.95	28.46	4.40	3.60	9.20	2.00	6.95	533.00
$S_3 B_3$	44.67	28.36	7.00	3.70	16.00	3.50	7.78	552.90
S_0	37.71	16.93	3.50	3.50	6.00	2.00	7.89	261.02
S_1	37.73	21.36	4.95	3.83	7.71	2.13	7.93	393.97
S_2	41.74	29.10	4.38	4.13	7.26	2.88	7.94	462.02
S_3	39.74	25.01	4.68	3.75	10.30	3.00	9.17	530.23
B_0	38.41	20.92	3.90	3.55	7.05	2.00	7.88	356.83
B_1	39.85	23.563	4.00	3.73	7.54	2.25	8.77	412.33
B_2	39.36	23.75	4.73	3.60	7.86	3.38	8.69	425.37
B_3	39.32	24.16	4.80	4.33	8.83	2.38	7.59	452.70
F-S	3.34*	5.01**	4.25*	1.38^{NS}	10.34**	2.40^{NS}	0.653^{NS}	478.95**
F-B	3.62*	0.4028^{NS}	2.22^{NS}	2.67^{NS}	5.78**	3.37*	0.579^{NS}	112.33**
F-SXB	2.66*	3.00*	3.78**	1.94^{NS}	5.18**	0.7692^{NS}	0.405^{NS}	176.93**
CD(S)	3.181	6.989	0.9192	-	2.340	-	-	48.302
CD(B)	3.181	-	-	-		1.37	-	48.302
CD(SxB)	6.363	13.979	1.9284	-	4.680	-	-	96.604

lowest values were 7.89 cm and 7.59 cm being recorded by S_0 (0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively.

4.2.1.3 .3 No. of branches plant^{-1}

4.2.1.3 .3 .1 No. of primary branches plant^{-1}

It is obvious from the data that the interaction of different levels of S and B had significant effect on the number of primary branches $plant^{-1}$. The maximum number of 7.0 was recorded by T_{16} (S_3B_3) and was significantly superior to the other treatments. The lowest value of 2.8 was recorded by T_3 (S_0B_2).

It has been observed that the main effect of different levels of S and B was also significant with regard to the parameter. Among the different levels of S and B, the highest value of 4.95 and 4.80 was recorded by S_1 (7.5 kg S ha^{-1}) and B_3. The smallest value of 3.5 and 3.9 was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.1.3 .3 .2 No. of secondary branches plant^{-1}

Analysis of the data shows that the number of secondary branches $plant^{-1}$ was not significantly influenced by the interaction of different levels of S and B. However the highest value of 5.5 was recorded by T_9 (S_2B_0) and the lowest value of 2.8 was recorded by T_3 (S_0B_2).

Among the different levels of S and B, S_2 (15.0 kg ha^{-1}) and B_3 (7.5 kg ha^{-1}) recorded the highest values of 4.13 and 4.33 respectively. The lowest values recorded were 3.50 and 3.55 respectively being shown by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}).

4.2.1.3 .4 Leaf area plant^{-1}

The critical examination of the data showed that the interaction between different levels of S and B registered significant effect on the leaf area $plant^{-1}$ at 40 DAS. It had been found that the highest value of 552.90 cm^2 was shown by T_{16} (S_3B_3) and was followed by T_{15} (S_3B_2) and T_{14} (S_3B_1) which were on par. The lowest value of 123.75 cm^2 was shown by T_1 (S_0B_0).

Among the individual effects of these nutrients which were also significant, the highest values of 530.23 cm^2 and 452.70 cm^2 were shown by S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively. The lowest values of 261.02 cm^2 and 356.83 cm^2 were shown by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.1.3 .5 Fresh weight plant^{-1}

Data analysis reveals the significant effect of interaction between different levels of S and B and the main effect of different levels of S. However no significance was observed for the main effect of different levels of B. Among the interaction effect, the values ranged from 9.62 g $plant^{-1}$ to 42.23 g $plant^{-1}$ recorded by T_7 (S_1B_2) and T_{11} (S_2B_2).

Among the different levels of S, S_2 (15.0 kg ha^{-1}) recorded the highest value of 29.10 g $plant^{-1}$ and was on par with S_3. The lowest value of 16.93 g $plant^{-1}$ was shown by S_0 (0 kg S ha^{-1}). Eventhough non significant the different levels of B produced values in the range of 20.93 g $plant^{-1}$and 24.16 g $plant^{-1}$ respectively being recorded by B_0 (0.0 kg B ha^{-1}) and B_3 (7.5 kg B ha^{-1}).

4.2.1.3 .6 Root spread

Perusal of the data indicated that the interaction between different levels of S and B had significant effect on the root spread of sesame at 40 DAS. T_{16} (S_3B_3) was the significantly superior treatment and recorded a value of 16 cm. The lowest value of 5.3 cm was shown by T_1 (S_0B_0).

The main effect of different levels of S and B also registered significant effect with regard to the parameter studied. It had been observed that S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest value of 10.30 cm and 8.83 cm and were significantly superior to the other levels of these nutrients. The lowest value of 6.00 cm and 7.05 cm was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.1.3 .7 Root volume

Statistical analysis of the data indicated that the interaction between different levels of S and B did not produce any significant effect on the root volume at 40 DAS. The values ranged between 1.5 ml and 4.0 ml produced by T_3 (S_0B_2) and T_{13} (S_3B_0) respectively.

Data analysis revealed that the main effect of different levels of S also did not have any significant effect and the values varied between 2.00 ml and 3.00 ml was produced by S_0 (0 kg S ha^{-1}) and S_3. But the main effect of different levels of B had significant effect on the parameter and the values ranged between 2.00 ml and 3.38 ml recorded by B_0 (0.0 kg B ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively.

4.2.1.4 **50 DAS** (Table 9)

4.2.1.4 .1 Height of plant

The height of the plant was significantly influenced by the interaction of different levels of S and B. Data analysis indicated that the highest value of 125.89 cm was recorded by T_{16} (S_3B_3) and was on par with T_8 (S_1B_3). The lowest value of 95.29 cm was recorded by T_1 (S_0B_0) and was on par with T_3 (S_0B_2).

Perusal of the data revealed that the main effect of different levels of S and B also registered significant effect on the height of the plant. Among the different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 113.93 cm and 113.82 cm produced by S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively. The lowest values of 108.57 cm and 109.72 cm were recorded by S_0 (0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively.

4.2.1.4 .2 Length of internodes

Statistical analysis of the data shows that the internodal length of sesame was significantly influenced by the application of different levels of S and B. Among the interaction effect, T_{16} (S_3B_3) recorded the highest value of 12.08 cm and was on par with T_8 (S_1B_3). The lowest value of 4.43 cm was recorded by T_2 (S_0B_1).

Table 9. Biometric characters of Sesame at 50 DAS

Treatments	Height(cm)	Fresh weight(g)	Number of branches		Root Characters		Length of internodes(cm)	Leaf area (cm^2)
			Primary	Secondary	Root Spread(cm)	Root Volume(ml)		
$S_0 B_0$	95.29	26.71	3.40	1.30	5.40	2.50	7.65	283.75
$S_0 B_1$	118.41	40.18	3.50	1.90	9.10	3.00	4.43	311.23
$S_0 B_2$	104.29	30.18	4.375	2.10	7.10	2.00	8.05	312.50
$S_0 B_3$	116.28	29.13	4.70	2.30	8.60	1.50	7.28	350.06
$S_1 B_0$	109.72	30.29	5.15	2.10	5.45	4.50	8.95	410.50
$S_1 B_1$	108.90	32.48	3.80	2.80	9.85	3.00	7.53	425.00
$S_1 B_2$	112.06	27.34	6.20	2.25	9.50	4.50	7.10	446.37
$S_1 B_3$	121.90	30.56	4.70	2.00	12.25	2.50	10.20	495.20
$S_2 B_0$	119.99	26.78	6.40	2.30	8.70	5.00	5.00	465.35
$S_2 B_1$	108.67	42.55	4.40	2.60	9.90	3.50	8.92	474.60
$S_2 B_2$	105.96	40.78	6.40	2.30	9.25	4.00	5.93	483.50
$S_2 B_3$	112.20	57.94	6.00	2.30	10.65	6.00	6.78	502.50
$S_3 B_0$	103.52	32.40	3.50	2.70	14.60	2.50	6.65	523.20
$S_3 B_1$	109.75	64.13	6.30	2.10	14.65	2.50	7.33	552.10
$S_3 B_2$	116.56	37.81	5.00	2.40	9.45	3.50	6.92	548.40
$S_3 B_3$	125.89	56.50	6.00	2.45	14.50	3.50	12.08	575.60
S_0	108.57	30.17	3.99	1.90	7.55	2.25	6.66	314.39
S_1	113.15	31.57	4.96	2.29	9.26	3.63	8.24	444.27
S_2	111.71	41.99	5.18	2.48	9.63	3.00	6.85	481.49
S_3	113.93	47.71	5.83	2.31	13.30	4.63	8.44	549.83
B_0	112.38	29.04	4.61	2.00	8.54	3.00	6.99	420.70
B_1	111.43	44.83	4.48	2.35	10.88	3.63	7.01	440.73
B_2	109.72	34.02	5.49	2.26	8.825	3.5	7.06	447.69
B_3	113.82	43.53	5.38	2.36	11.50	3.38	9.08	480.84
F-S	5.87**	6.53**	9.11**	3.06^{NS}	7.96**	4.49*	4.64*	478.95**
F-B	4.46*	5.31 **	4.27*	1.46^{NS}	3.95*	0.324^{NS}	5.67**	112.33**
F-SXB	3.51 *	4.53**	3.91**	1.15^{NS}	3.06*	1.01^{NS}	4.49**	176.93**
CD(S)	7.631	9.934	0.7572	-	2.585	1.430	1.294	48.302
CD(B)	7.631	9.934	0.7572	-	2.585	-	1.294	48.302
CD(SxB)	15.263	19.868	1.515	-	5.169	-	2.589	96.604

Among the different levels of S and B applied, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest value of 8.44 cm and 9.08 cm respectively. The lowest values recorded were 6.66 cm and 6.99 cm respectively by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.1.4 .3 No. of branches plant^{-1}

4.2.1.4 .3 .1 No. of primary branches plant^{-1}

Perusal of the data revealed that the application of different levels of S and B had significant effect on the number of primary branches $plant^{-1}$ at 50 DAS. Among the interaction effect between different levels of S and B, the highest value of 6.4 was shown by T_9 (S_2B_0) and T_{11} (S_2B_2) followed by T_{14} (S_3B_1) and T_7 (S_1B_2) and were on par with each other. The lowest value of 3.4 was recorded by T_1 (S_0B_0) and was on par with T_2 (S_0B_1).

Coming to the main effect of S and B, the significant influence of the different levels of S and B was recorded and the highest values of 5.83 and 5.49 were recorded by S_3 (30.0 kg S ha^{-1}) and B_2 (5 kg B ha^{-1}). The lowest values recorded were 3.99 and 4.48 by S_0 (0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively.

4.2.1.4 .3 .2 No. of secondary branches plant^{-1}

It has been observed that the application of different levels of S and B and their interaction had no significant effect on the number of secondary branches $plant^{-1}$. The highest value of 2.8 was recorded by T_6 (S_1B_1) and the lowest value of 1.3 was recorded by T_1 (S_0B_0).

Among the different levels of S and B, S_2 (15.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 2.48 and 2.36 respectively. The lowest values of 1.90 and 2.00 were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

4.2.1.4 .4 Leaf area plant^{-1}

Perusal of the data showed that leaf area $plant^{-1}$ was significantly influenced by the interaction between different levels of S and B. The highest and significant value of 575.60 cm^2 was shown by T_{16} (S_3B_3). The lowest value of 283.75 cm^2 was recorded by T_1 (S_0B_0).

Coming to the individual effects of different levels of S and B which were also significant, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) showed the highest values of 549.83 cm^2 and 480.84 cm^2 respectively. These were significantly superior to the other levels. The lowest values of 314.39 cm^2 and 420.70 cm^2 were observed in S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.1.4 .5 Fresh weight plant^{-1}

Critical examination of the data showed that the interaction between different levels of S and B had significant effect on the fresh weight of the plant at 50 DAS. The values ranged from 26.71 g $plant^{-1}$to 64.13 g $plant^{-1}$ being recorded by T_1 (S_0B_0) and T_{14} (S_3B_1) respectively. T_{14} (S_3B_1) was on par with T_{12} (S_2B_3) and T_{16} (S_3B_3).

The main effect of different levels of S and B also registered significant effect on the fresh weight of the plant. Among the different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) recorded the highest values of 47.71 g $plant^{-1}$ and 44.83 g $plant^{-1}$and the lowest values of 30.17 g $plant^{-1}$and 29.04 g $plant^{-1}$were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

4.2.1.4 .6 Root spread

Statistical analysis of the data shows that the root spread of sesame was significantly influenced by the application of different levels of S and B and their interaction with each other. The highest value of 14.65 cm was recorded by T_{14} (S_3B_1) followed by T_{13} (S_3B_0) and were on par with each other. The lowest value of 5.4 cm was recorded by T_1 (S_0B_0) and was on par with T_5 (S_1B_0).

Among the different levels of these nutrients, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 13.30 cm and 11.50 cm respectively and were significantly superior to the other levels. The lowest values of 7.55 cm and 8.54 cm were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.1.4 .7 Root volume

Perusal of the data showed that the root volume of sesame was significantly influenced by the application of different levels of S only. Though the interaction between different levels of S and B could not register any significant effect, the highest value of 6 ml was recorded by T_{12} (S_2B3) followed by T_9 (S_2B_0). The lowest value of 1.5 ml was shown by T_4 (S_0B_3).

Among the different levels of S, S_3 (30.0 kg S ha^{-1}) was the significantly superior level which recorded a value of 4.63 ml. The lowest value of 2.25 ml was shown by S_0. The different levels of B did not produce any significant effect. The values ranged between 3.00 and 3.63 shown by B_0 (0.0 kg B ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively.

4.2.1.5 Harvest (Table 10)

4.2.1.5 .1 Height of plant

Detailed statistical examination of the data shows that the height of the plant at the time of harvest was significantly affected by the interaction of different levels of S and B. The highest value of 124.07 cm was recorded by T_{16} (S_3B_3) and was on par with T_9 (S_2B_0) and T_{13} (S_3B_0). The lowest value of 94.94 cm was recorded by T_1 (S_0B_0).

Among the different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 117.31 cm and 115.34 cm. The lowest values recorded were 105.04 cm and 106.71 cm by S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

4.2.1.5 .2 Length of internodes

Statistical analysis of the data presented shows that neither the interaction between different levels of S and B nor their main effects could register any significant effect on the length of internodes at the time of harvest. It had been observed that the values ranged between 10.25 cm recorded by T_2 (S_0B_1) and 5.63 cm by T_9 (S_2B_0).

Table 10. Biometric characters of sesame at the time of harvest

Treatments	Height(cm)	Fresh weight(g)	No. of branches		Root Characters		Length of internodes (cm)
			Primary	Secondary	Root Spread(cm)	Root Volume(ml)	
$S_0 B_0$	94.94	23.28	2.70	1.38	7.20	2.60	7.34
$S_0 B_1$	108.79	25.24	3.40	3.50	14.95	3.50	10.25
$S_0 B_2$	100.24	34.85	3.10	3.00	10.20	5.50	8.30
$S_0 B_3$	116.2	39.90	3.00	2.30	12.35	4.00	6.58
$S_1 B_0$	117.12	38.00	4.00	3.30	17.60	4.50	6.70
$S_1 B_1$	100.5	37.94	4.00	4.00	10.25	3.00	6.68
$S_1 B_2$	96.06	39.00	3.00	2.85	12.85	3.00	8.33
$S_1 B_3$	114.12	73.05	3.90	2.80	13.50	8.00	6.58
$S_2 B_0$	120.66	79.45	4.65	3.00	19.25	8.50	5.63
$S_2 B_1$	105.88	42.05	3.20	1.98	15.60	7.00	6.63
$S_2 B_2$	117.43	69.91	4.20	2.65	14.25	6.00	7.63
$S_2 B_3$	106.96	54.80	3.13	2.25	15.90	7.00	7.60
$S_3 B_0$	117.45	52.93	4.50	2.50	14.15	8.50	5.85
$S_3 B_1$	114.58	120.10	3.30	3.05	20.00	9.00	7.05
$S_3 B_2$	113.12	133.50	4.50	4.00	19.70	10.00	5.93
$S_3 B_3$	124.07	147.00	4.50	2.88	22.00	11.00	6.68
S_0	105.04	30.82	3.05	2.47	11.18	4.00	8.11
S_1	106.95	46.99	3.73	3.11	13.55	4.65	7.07
S_2	112.73	61.55	3.79	2.54	16.25	7.13	6.87
S_3	117.31	113.38	4.20	3.24	18.96	9.50	6.38
B_0	106.71	48.90	3.48	2.54	14.55	5.63	6.38
B_1	107.44	55.84	3.96	3.13	15.20	6.00	7.65
B_2	112.54	69.31	3.70	3.13	14.25	6.03	7.54
B_3	115.34	78.69	3.63	2.56	15.94	7.63	6.86
F-S	4.25*	41.11**	4.28*	3.96 *	9.78 **	22.42 **	2.60^{NS}
F-B	3.52*	31.98**	0.778 NS	2.91^{NS}	3.42*	2.81^{NS}	1.76^{NS}
F-SXB	2.63*	31.98**	1.69^{NS}	2.88*	2.65*	2.632*	1.23^{NS}
CD(S)	8.167	6.281	0.694	0.589	3.243	1.599	-
CD(B)	8.167	6.281	-	-	3.243	-	-
CD(SXB)	16.334	12.562	-	1.180	6.487	3.197	-

Among the different levels of S and B, S_0 (0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) recorded the highest values of 8.11 cm and 7.65 cm. The lowest value recorded was 6.38 cm and by S_3 (30 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}).

4.2.1.5 .3 No. of branches plant^{-1}

4.2.1.5 .3.1No. of primary branches plant^{-1}

Perusal of the data indicated that the interaction between different levels of S and B applied had no significant effect on the number of primary branches $plant^{-1}$. However the values varied between 2.70 and 4.65 recorded by T_1 (S_0B_0) and T_9 (S_2B_0) respectively.

The main effect of different levels of S applied registered significant effect on the parameter. The values ranged from 3.05 to 4.20 being recorded by S_0 (0 kg S ha^{-1}) and S_3 (30.0 kg S ha^{-1}) respectively. The levels of B could not produce any significant effect on this parameter and the range of values were between 3.48 and 3.96 recorded by B_0 (0.0 kg B ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively.

4.2.1.5 .3 .2 No. of secondary branches plant^{-1}

Critical scrutiny of the data indicated that the interaction between different levels of S and B and the main effect of different levels of S were significant with regard to the number of secondary branches $plant^{-1}$ at the time of the harvest of the crop. Among the interaction effect, T_6 (S_1B_1) and T_{15} (S_3B_2) registered the highest value of 4.00 followed by T_2 (S_0B_1) and were on par with each other. The lowest value of 1.38 was shown by T_1 (S_0B_0).

Among the different levels of S applied, S_3 (30.0 kg S ha^{-1}) recorded the highest value of 3.24 and was on par with S_1. The lowest value of 2.47 was shown by S_0. The different levels of B could not produce any significant effect on the parameter studied. However the values range from 2.54 to 3.13 produced by B_0 (0.0 kg B ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively.

4.2.1.5 .4 Fresh weight plant^{-1}

It had been statistically observed that the fresh weight plant^{-1} was significantly influenced by the interaction between different levels of S and B and the main effect of S and B individually.

Coming to the interaction effect, the values ranged from 23.28 g plant^{-1} to 147 g plant^{-1}produced by T_{16} (S_3B_3) and T_1 (S_0B_0) respectively. T_{16} (S_3B_3) was significantly superior to the other treatment combinations.

Among the different levels of S and B applied, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 113.38 g plant^{-1} and 78.69 g plant^{-1} respectively. The lowest values recorded were 30.82 g plant^{-1} and 48.90 g plant^{-1} produced by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.1.5 .5 Root spread

Perusal of the data revealed that the application of treatments could produce significant effect on the root spread of sesame at the time of harvest. Among the interaction effect of different levels of S and B, T_{16} (S_3B_3) recorded the highest value of 22 cm followed by T_{14} (S_3B_1) and T_{15} (S_3B_2) and were on par with each other. The lowest value of 7.2 cm was shown by T_1 (S_0B_0).

Among the different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 18.96 cm and 15.94 cm respectively. The lowest values of 11.18 cm and 14.25 cm were shown by S_0 (0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively.

4.2.1.5 .6 Root volume

The interaction between different levels of S and B and the main effect of S could produce significant effect on the root volume of sesame at the time of harvest. Among the interaction effect, the highest value of 11 ml was shown by T_{16} (S_3B_3) followed by T_{15} (S_3B_2) and T_{14} (S_3B_1) and were on par with each other. The lowest value of 2.60 ml was produced by T_1 (S_0B_0).

Among the different levels of S, S_3 (30.0 kg S ha^{-1}) recorded the highest value of 9.50 ml and the lowest value of 4.00 ml was recorded by S_0. S_3 (30.0 kg S ha^{-1}) was significantly superior to the other levels. The main effect of B did not produce any significant effect for the parameter. However the values ranged between 5.63 ml and 7.63 ml being shown by B_0 (0.0 kg B ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively.

4.2.2 Effect of treatments on the yield and yield attributes of Sesame (Table 11 and 12)

4.2.2.1 Days to first flowering

It can be observed from the data that the interaction between different levels of S and B had significant effect on the days to first flowering of the crop. The smallest value of 33.00 was observed with T_{14} (S_3B_1) and T_{16} (S_3B_3). The highest value of 37.00 was recorded by T_1 (S_0B_0).

As regard to the individual effects of different levels of S and B no significance was noticed. S_3 (30.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) recorded the lowest values of 33.50 and 33.13 respectively. The highest values of 35.00 and 35.75 were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.2.2 Days to fifty per cent flowering

As in the case of days to first flowering, the days to fifty per cent flowering was also significantly effected by the interaction between different levels of S and B. The values ranged between 36.00 and 46.00 being shown by T_{14} (S_3B_1) and T_1 (S_0B_0) respectively.

The main effects of these nutrients were non significant with regard to this parameter. However the lowest values of 38.12 and 37.00 were shown by S_3 (30.0 kg S ha^{-1}) and B_1 respectively. The highest values recorded were 41.00 and 42.50 being shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

Table 11. Dry matter, yield and yield attributes of sesame at the time of harvest

Treatments	Dry matter yield (kg ha^{-1})	Seed yield (kg ha^{-1})			Bhusa yield (t ha^{-1})	Harvest Index	Days to first flowering	Days to fifty per cent flowering
		I crop	II Crop	Pooled data				
$S_0 B_0$	1403.00	585.94	537.50	561.72	13.63	0.417	37.00	46.00
$S_0 B_1$	1776.50	1104.17	1113.17	1108.67	19.59	0.621	34.50	39.00
$S_0 B_2$	1871.50	1057.29	1055.73	1056.51	22.85	0.565	34.00	39.00
$S_0 B_3$	1694.00	940.11	1020.56	980.33	13.67	0.555	34.50	40.00
$S_1 B_0$	2344.50	734.38	732.81	733.59	14.72	0.313	36.50	40.00
$S_1 B_1$	2500.00	1010.38	1041.40	1025.89	14.65	0.404	32.00	36.00
$S_1 B_2$	2331.50	968.75	938.54	953.65	14.99	0.416	33.00	38.00
$S_1 B_3$	5174.50	1091.15	1084.38	1087.76	21.59	0.211	34.50	40.50
$S_2 B_0$	4219.00	953.12	1063.54	1008.33	22.48	0.226	35.50	44.00
$S_2 B_1$	2506.00	979.17	1055.72	1017.44	14.02	0.391	33.00	37.00
$S_2 B_2$	3712.00	1127.61	1128.65	1128.13	23.30	0.304	34.00	39.00
$S_2 B_3$	2910.00	1028.65	1034.89	1031.77	18.27	0.353	33.00	41.50
$S_3 B_0$	2810.00	953.12	948.95	951.04	17.63	0.339	34.00	40.00
$S_3 B_1$	5691.50	1377.61	1172.94	1275.27	25.92	0.242	33.00	36.00
$S_3 B_2$	4800.00	895.83	894.27	895.05	15.0	0.187	34.00	38.00
$S_3 B_3$	3812.50	1460.94	1407.30	1434.12	19.93	0.383	33.00	38.50
S_0	1686.25	921.87	931.74	926.81	15.18	0.547	35.00	41.00
S_1	3087.63	951.16	949.28	950.22	17.49	0.308	34.00	38.63
S_2	3336.75	1022.14	1070.69	1046.42	20.52	0.306	33.88	40.38
S_3	4278.50	1171.87	1105.86	1138.87	22.62	0.274	33.50	38.12
B_0	2694.13	806.64	820.70	813.67	16.63	0.299	35.75	42.50
B_1	3118.50	1117.83	1095.81	1106.82	19.04	0.358	33.13	37.00
B_2	3178.75	1012.37	1004.30	1008.33	18.54	0.318	33.75	38.50
B_3	3397.75	1130.21	1136.78	1133.49	21.61	0.333	33.75	40.13
F-S	22.60**	6.23**	25.58**	40.51 **	4.77**	388.84**	0.0820^{NS}	0.070^{NS}
F-B	5.71**	33.36**	84.85**	90.23 **	4.98**	93.67**	3.705*	3.56*
F-SXB	6.20**	13.77**	28.31**	25.66 **	2.85*	649.76**	3.3805*	2.95*
CD(S)	679.171	78.128	45.969	15.26	7.023	0.1476	-	-
CD(B)	679.171	78.128	45.969	15.26	7.023	0.1476	-	-
CD(SXB)	1358.342	156.255	91.938	30.52	14.04	0.2952	2.52011	3.484

Table 12.Yield attributes of sesame

Treatments	No of capsules plant^{-1}	No. of seeds capsule^{-1}	Capsule dry weight (kg ha^{-1})	Seed Dry weight (kg ha^{-1})	Shelling Per cent	Oil Content (%)	Oil Yield (kg ha^{-1})	1000-seed weight(g)	B:C Ratio
$S_0 B_0$	20.00	60.00	2447.55	585.94	22.53	43.60	255.46	2.40	2.05
$S_0 B_1$	33.50	44.50	4911.75	1104.17	22.00	45.63	503.83	2.46	3.68
$S_0 B_2$	28.50	59.00	3696.30	1057.29	28.30	51.10	540.27	2.50	3.36
$S_0 B_3$	30.50	60.00	4612.05	940.11	20.34	48.03	451.53	2.60	2.86
$S_1 B_0$	58.00	64.00	6443.55	734.38	11.35	53.43	392.37	2.70	2.36
$S_1 B_1$	46.00	58.00	4045.95	1010.38	24.49	51.95	524.89	2.78	2.38
$S_1 B_2$	23.50	57.00	2913.75	968.75	29.12	51.35	497.45	2.79	2.64
$S_1 B_3$	53.50	57.00	5477.85	1091.15	19.91	52.71	575.14	2.76	2.88
$S_2 B_0$	42.00	64.00	7076.25	953.12	14.23	53.03	505.43	2.62	2.56
$S_2 B_1$	27.00	63.50	2597.40	979.17	31.00	53.80	526.79	2.87	3.24
$S_2 B_2$	42.00	56.00	3979.35	1127.61	28.32	52.05	586.92	2.84	3.55
$S_2 B_3$	41.50	63.00	4279.05	1028.65	24.02	54.85	564.21	2.87	3.11
$S_3 B_0$	40.50	59.00	5644.35	953.12	12.04	57.64	549.37	2.65	3.28
$S_3 B_1$	41.00	64.00	4045.95	1377.61	26.02	57.83	796.67	2.98	4.52
$S_3 B_2$	48.50	62.50	7159.5	895.83	12.26	55.35	495.84	2.86	2.81
$S_3 B_3$	58.50	73.50	7908.75	1460.94	23.94	59.45	868.52	2.88	4.38
S_0	28.13	55.88	3338.33	921.87	23.29	47.09	434.10	2.49	2.99
S_1	45.25	59.00	4720.275	951.16	18.56	52.36	498.02	2.76	3.07
S_2	38.13	61.63	5061.60	1022.14	24.39	53.43	546.12	2.80	3.32
S_3	47.13	64.75	6189.64	1171.87	21.22	57.57	674.64	2.84	3.75
B_0	40.13	61.75	5440.39	806.64	15.04	51.92	418.80	2.59	2.81
B_1	36.88	57.50	3862.80	1117.83	25.88	52.30	584.62	2.77	3.70
B_2	35.63	58.63	4437.23	1012.370	24.50	52.46	531.08	2.75	3.20
B_3	46.000	63.38	5569.43	1130.21	22.05	53.76	607.60	2.78	3.41
F-S	17.23**	2.05^{NS}	9.06**	6.23**	3.31*	45.96**	286.33**	1.2.48**	6.55**
F-B	4.99*	1.06^{NS}	4.40*	33.36**	10.52**	5.59**	186.48**	7.15**	6.28**
F-SXB	5.973**	1.10^{NS}	3.10*	13.77**	3.26*	2.67 *	36.76**	1.92^{NS}	4.25**
CD(S)	6.250	-	1176.022	78.128	4.48	0.6361	49.697	0.3984	0.2441
CD(B)	6.250	-	1176.022	78.128	4.48	0.6361	49.697	0.3984	0.2441
CD(SXB)	12.501	-	2352.043	156.255	8.96	1.272	99.394	-	0.4882

4.2.2.3 Number of capsules plant^{-1}

The data on the number of capsules plant^{-1} are presented in Table 12. It shows significant effect of the interaction between different levels of S and B. The highest value of 58.50 was shown by T_{16} (S_3B_3) followed by T_5 (S_1B_0) and T_8 (S_1B_3) which were on par with each other. The lowest number of 20 was recorded by T_1 (S_0B_0).

Among the main effect of different levels of S and B, significant relation had been noticed. The highest value of 47.13 and 46.00 was shown by S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively. The lowest values of 28.13 and 35.63 were recorded by S_0 (0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively.

4.2.2.4 Number of seeds capsule^{-1}

Perusal of the data revealed that the number of seeds capsule $^{-1}$ was not significantly influenced by the application of different levels of S and B or their interaction with each other. However the highest value of 73.50 was shown by T_{16} (S_3B_3) followed by T_5 (S_1B_0). The lowest value of 44.50 was recorded by T_2 (S_0B_1).

Among the different levels of S and B, S_3 (30.0 kg ha^{-1}) recorded the highest value of 64.75 followed by S_2 and the lowest value of 55.88 was shown by S_0 (0 kg ha^{-1}). B_3 (7.5 kg B ha^{-1}) recorded the highest value of 63.38 and the lowest value of 57.50 was shown by B_1 (2.5 kg B ha^{-1}).

4.2.2.5 Dry weight of capsule

It can be statistically inferred from the data that the interaction between different levels of S and B had significant effect on the parameter. The highest value of 7908.75 kg ha^{-1} was shown by T_{16} (S_3B_3) and was on par with T_{15} (S_3B_2). The lowest value of 2447.55 kg ha^{-1} was recorded by T_1 (S_0B_0).

Analysis of the data revealed that the main effects of different levels of S and B were also significant with regard to the parameter studied. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 6189.64

kg ha^{-1} and 5569.43 kg ha^{-1}. The lowest values of 3338.33 kg ha^{-1} and 3862.80 kg ha^{-1} were recorded by S_0 (0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively.

4.2.2.6 Thousand seed weight

Data regarding the thousand seed weight of the crop recorded at harvest are presented in Table. On critical examination of the data, it could be inferred that the interaction between different levels of S and B could not register any significant effect. However, the highest value of 2.98 g was shown by T_{14} (S_3B_1). The lowest value of 2.40 g was recorded by T_1 (S_0B_0).

The different levels of S and B individually could register significant effect on this parameter under consideration. Among the different levels, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) registered the highest values of 2.84 g and 2.78grespectively. The lowest values of 2.49 g and 2.59 g were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.2.7 Grain yield

Data on the first crop shows that the application of different levels of S and B had significant effect on the grain yield. Among the interaction effect, the highest value of 1460.94 kg ha^{-1} was recorded by T_{16} (S_3B_3) followed by T_{14} (S_3B_1) and were on par with each other. The lowest value of 585.94 kg ha^{-1} was recorded by T_1 (S_0B_0).

Among the different levels of these nutrients, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 1103.51 kg ha^{-1} and 1130.21 kg ha^{-1}. These were significantly superior to their other lower levels. The lowest values of 921.87 kg ha^{-1} and 806.64 kg ha^{-1} were shown by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

For the second crop also analysis of the data shows the significant influence of the interaction between different levels of S and B and their individual effects. Among the interaction effect as in the case of the first crop, the highest value of 1407.30 kg ha^{-1} was recorded by T_{16} (S_3B_3) and was significantly superior to other treatment combinations. This was followed by T_{14} (S_3B_1). The lowest value of 537.50 kg ha^{-1} was recorded by T_1 (S_0B_0). All the treatments recorded significantly higher values than it.

Among the individual effects of different levels of these nutrients, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 1105.86 kg ha^{-1} and 1136.78 kg ha^{-1}respectively. These were on par with S_2 (15.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively. The lowest values of 931.74 kg $ha^{-1}$and 820.70 kg ha^{-1} were shown by S_0 and B_0 respectively.

The pooled data for both the years also revealed the significant effect of the interaction between different levels of S and B. The highest value of 1434.12 kg ha^{-1} was indicated by T_{16} (S_0B_0). This was significantly superior to the other treatment combinations. The lowest value of 561.72 kg ha^{-1} was recorded by T_1 (S_0B_0).

Regarding the main effects of these nutrients, S_3 and B_3 showed the significantly highest values of 1133. 87 kg ha^{-1} and 1133.49 kg ha^{-1} respectively. S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) registered the lowest values of 921.88 kg ha^{-1} and 813.67 kg ha^{-1} respectively.

4.2.2.8 Bhusa yield

Perusal of the data indicated that the bhusa yield of sesame was significantly influenced by the interaction of different levels of S and B and their individual effects. It had been observed that among the interaction effects, the highest value of 25.92 t ha^{-1} was recorded by T_{14} (S_3B_1) and was on par with T_8 (S_1B_3). The lowest value of 13.63 t ha^{-1} was produced by T_1 (S_0B_0).

Among the different levels of S and B, S_3 (30.0 kg ha^{-1}) and B_3 (7.5 kg ha^{-1}) recorded the highest values of 22.62 t ha^{-1} and 21.61 t ha^{-1} respectively. The lowest values of 15.18 kg ha^{-1} and 16.63 t ha^{-1} were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.2.9 Dry matter yield

Perusal of the data showed that the interaction between S and B had significant effect on the dry matter yield of sesame. The highest value of 5691.50 kg ha^{-1} was shown by T_{14} (S_3B_1) and was on par with T_8 (S_1B_3) and T_{15} (S_3B_2). The lowest value of 1403 kg ha^{-1} was recorded by T_1 (S_0B_0) and was on par with T_4 (S_0B_3) and T_2 (S_0B_1).

Among the different levels of S and B individually, S_3 (30.0 kg ha^{-1}) and B_3 (7.5 kg ha^{-1}) recorded the highest value of 4278.50 kg ha^{-1} and 3397.75 kg ha^{-1} respectively. S_3 (30.0 kg S ha^{-1}) was significantly superior to the other levels while B_3 (7.5 kg B ha^{-1}) was on par with B_2 (5.0 kg B ha^{-1}). The lowest value recorded were 1686.25 kg ha^{-1} and 2694.13 kg ha^{-1} produced by S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.2.10 Harvest Index

Perusal of the data revealed the significant influence of the interaction between different levels of S and B on the harvest index of the crop. The highest value of 0.621 was recorded by T_2 (S_0B_1) followed by T_3 (S_0B_2). The lowest value of 0.187 was shown by T_{15} (S_3B_2).

Among the levels of S and B, S_0 (0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 0.547 and 0.333 respectively. The lowest values of 0.274 and 0.299 were shown by S_3 (30 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

4.2.2.11 Shelling Percentage

Critical examination of the data revealed that the interaction between different levels of S and B exhibited significant influence on the shelling percentage of the crop. T_{10} (S_2B_1) recorded the highest value of 31 per cent and was on par with T_7 (S_1B_2) and T_{11}. The lowest value of 11.35 per cent was shown by T_5 (S_1B_0).

Among the different levels of these nutrients, the highest values of 24.39 and 25.88 were recorded by S_2 (15.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively.

The lowest values recorded were 18.56 and 15.04 per cent recorded by S_1 (7.5 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.2.12 B:C Ratio

Perusal of the data indicated that the B:C ratio of the crop at harvest was significantly influenced by the application of different levels of S and B. The highest value of 4.52 was observed with T_{14} (S_3B_1) which was found to be on par with T_{16} (S_3B_3). The lowest value of 2.05 was observed with T_1 (S_0B_0).

Among the individual effects of these nutrients, S_3 (30 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) registered the highest values of 3.75 and 3.70 respectively. The lowest values of 2.99 and 2.81 were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.2.13 Oil content

Perusal of the data indicated that the application of different levels of S and B and their interaction had significant effect on the oil content of seed. The highest values of 59.45 per cent were shown by T_{16} (S_3B_3) followed by T_{14} (S_3B_1) and were on par with each other. T_1 (S_0B_0) recorded the lowest value of 43.60 per cent and was on par with T_2 (S_0B_1).

Among the different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 57.57 per cent and 53.76 per cent respectively. S_0 (0 kg S ha^{-1}) and B_0 (0 B kg ha^{-1}) showed the lowest values of 47.09 per cent and 51.92 per cent respectively.

4.2.3 Effect of treatments on the quality parameters of sesame (Table 13)

4.2.3.1 Grain protein

Perusal of the data showed the significant effect of the interaction between different levels of S and B. It had been found that the highest value of 17.50 per cent was recorded by T_{16} (S_3B_3) followed by T_{16} (S_3B_2) and were on par with each other. The lowest value of 12.19 per cent was observed in T_1 (S_0B_0).

Table 13. Quality characters of sesame

Treatments	Grain protein (%)	Saponification Value	Acid Value	Iodine Value
$S_0 B_0$	12.19	224.00	2.99	102.00
$S_0 B_1$	12.81	213.13	2.90	107.30
$S_0 B_2$	13.13	201.65	2.84	109.50
$S_0 B_3$	13.31	209.50	2.60	105.50
$S_1 B_0$	13.19	199.24	2.20	108.00
$S_1 B_1$	14.06	186.12	2.32	110.00
$S_1 B_2$	14.44	202.35	2.70	107.00
$S_1 B_3$	15.56	199.58	2.15	108.50
$S_2 B_0$	13.13	211.94	2.63	112.00
$S_2 B_1$	14.25	197.60	2.60	117.50
$S_2 B_2$	14.81	189.47	2.16	109.00
$S_2 B_3$	15.75	199.31	2.15	115.00
$S_3 B_0$	17.06	183.80	2.10	111.00
$S_3 B_1$	17.25	189.37	2.06	125.00
$S_3 B_2$	17.44	180.29	2.04	117.50
$S_3 B_3$	17.50	177.86	2.00	120.
S_0	12.88	212.07	2.83	106.08
S_1	14.31	196.82	2.34	108.38
S_2	14.50	199.58	2.39	113.38
S_3	17.31	182.83	2.05	118.38
B_0	13.88	204.75	2.52	108.25
B_1	14.63	196.56	2.47	114.95
B_2	14.94	193.44	2.44	110.75
B_3	15.56	196.56	2.22	112.25
F-S	12.73**	15.55**	51.17**	55.42**
F-B	6.18**	5.95**	13.76**	14.52**
F-SXB	9.18**	2.67*	4.29**	4.26**
CD(S)	1.543	14.28	0.3401	2.217
CD(B)	1.543	14.28	0.3401	2.217
CD(SXB)	3.087	29.56	0.6803	4.434

Among the different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 17.31 per cent and 15.56 per cent. The lowest values of 14.31 per cent and 13.88 per cent were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.3.2 Oil Constants

4.2.3.2.1 Saponification value

Perusal of the data revealed that the interaction between different levels of S and B had significant effect on the saponification value. The values ranged from 177.86 to 224.00 recorded by T_1 (S_0B_0) and T_{16} (S_3B_3) respectively.

The main effect of S and B levels were also found to be significant and the highest values of 212.07 and 204.75 was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively. The lowest values were 182.83 and 193.44 being recorded by S_3 (30 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively.

4.2.3.2 .2 Acid value

Significant effect of the interaction between different levels of S and B had been observed. The values ranged between 2.00 and 2.99 recorded by T_{16} (S_3B_3) and T_1 (S_0B_0) respectively

Coming to the main effects of S and B, the highest value of 2.83 and 2.52 were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively. The lowest values recorded were 2.05 and 2.22 shown by S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}).

4.2.3.2.3 Iodine value

The interaction between different levels of S and B had been found to be significant for the iodine value of the crop. Data analysis showed a range of values between 102 and 125 recorded by T_{14} (S_3B_1) and T_1 (S_0B_0). T_{14} (S_3B_1) was significantly superior to the other treatment combinations.

The main effect of S and B also showed significance with regard to the parameter. Among the levels of S, S_3 (30.0 kg S ha^{-1}) recorded the significantly highest value of 118.38 and the lowest value was noticed with S_0 (0 kg S ha^{-1}) as 106.08. The different levels of B also showed significance and the maximum value was recorded with B_1 (2.5 kg B ha^{-1}) as 114.95 which was significantly highest among the other levels. The lowest value of 108.25 was shown by B_0 (0 kg B ha^{-1}).

*4.2.3.3 **Fractionation of Oil*** (Table 14)

4.2.3.3.1 Palmatic acid

It is evident from the data that the interaction between different levels of S and B and their main effects had significant influence on the palmatic acid content of sesame oil. The highest value of 11.92 per cent among the interaction effect was recorded by T_1 (S_0B_0) and was significantly superior to others. The lowest value of 8.55 per cent was recorded by T_5 (S_1B_0). All the treatments were significantly superior to it.

Regarding the individual effects of different levels of S and B, S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) recorded the highest values of 10.82 per cent and 10.90 per cent respectively. The lowest values recorded were 9.85 per cent and 9.92 per cent being shown by S_1 (7.5 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively.

4.2.3.3.2 Stearic acid

It is explicit from the data that the different levels of S and B and their interaction had significant effect on the Stearic acid content of sesame oil. T_5 (S_1B_0) recorded the highest value of 12.24 per cent followed by T_1 (S_0B_0). The lowest value recorded was 4.17 per cent by T_8 (S_1B_3).

S_1 (7.5 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) recorded the highest values of 7.27 per cent and 8.03 per cent respectively. The lowest values recorded were 6.14 per cent and 5.99 per cent being shown by S_2 (15.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively.

Table 14. Fatty acid composition of sesame oil (%)

Treatments	Palmatic acid	Stearic acid	Oleic acid	Linoleic acid
$S_0 B_0$	11.92	7.41	36.81	34.44
$S_0 B_1$	10.28	5.84	40.30	43.13
$S_0 B_2$	9.84	6.14	42.42	41.51
$S_0 B_3$	11.25	7.08	42.94	38.00
$S_1 B_0$	8.55	12.24	41.93	39.93
$S_1 B_1$	10.62	6.43	40.91	42.00
$S_1 B_2$	10.02	6.23	41.12	42.53
$S_1 B_3$	10.19	4.17	39.41	42.32
$S_2 B_0$	10.23	6.05	41.05	41.22
$S_2 B_1$	9.80	6.19	42.20	41.74
$S_2 B_2$	10.08	6.13	42.15	41.40
$S_2 B_3$	10.72	6.18	41.50	41.45
$S_3 B_0$	10.65	6.42	43.54	39.20
$S_3 B_1$	9.63	6.04	41.71	44.42
$S_3 B_2$	9.76	6.23	41.63	41.91
$S_3 B_3$	10.75	6.55	41.08	41.72
S_0	10.82	6.61	40.62	39.27
S_1	9.85	7.27	40.84	41.70
S_2	10.20	6.14	41.73	41.45
S_3	10.20	6.31	41.99	41.81
B_0	10.90	8.03	40.83	38.70
B_1	10.08	6.12	41.28	42.82
B_2	9.92	6.18	41.83	41.84
B_3	10.17	5.995	41.23	40.87
F-S	116.76**	3.77*	3015.24**	24989.60**
F-B	132.11**	14.24**	5179.56**	41868.57**
F-S.B	85.47**	11.28**	3140.43**	13084.60**
CD - S	0.15642	1.069	0.05752	0.03300
CD - B.	0.15642	1.069	0.05752	0.03300
CD - S.B	0.31284	2.137	0.11503	0.06601

4.2.3.3.3 Oleic acid

It could be inferred from the data that the parameter was significantly influenced by the application of different treatments. The highest value of 43.54 per cent was recorded by T_{13} (S_3B_0) and was significantly superior to the others. The lowest value recorded was 36.81 per cent being shown by T_1 (S_0B_0). All the treatments registered significantly higher values than it.

Considering the main effects of S and B, S_3 (30 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) recorded the highest values of 41.99 per cent and 41.83 per cent respectively. The lowest values of 40.62 per cent and 40.83 per cent were shown by S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

4.2.3.3.4 Linoleic acid

It is obvious from the data that the linoleic acid content of sesame oil was significantly influenced by the application of S and B. T_{14} (S_3B_1) showed the highest value of 44.42 per cent which was significantly superior to all the other treatments. The lowest value of 34.44 per cent was recorded by T_1 (S_0B_0).

Regarding the individual effects of S and B, it had been observed that the highest values of 41.81 per cent and 41.84 per cent were recorded by S_3 (30 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively. The lowest values recorded were 39.27 per cent and 38.70 per cent being shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively. These were significantly lower than the other levels of these nutrients.

4.2.4 Effect of treatments on the nutrient concentration in plant parts at harvest

4.2.4.1 Bhusa (Table 15 a and 15 b)

4.2.4.1.1 Nitrogen

In the first crop, the N content of sesame was significantly influenced by the application of S and B. The interaction of S and B had had much significance on the parameter. T_{16} (S_3B_3) recorded the highest value of 1.520 per cent followed

Table 15a. Nutrient concentration of bhusa at harvest of the first crop (%)

Treatments	N	P	K	Ca	Mg	S
$S_0 B_0$	0.301	0.310	0.730	2.11	0.864	0.210
$S_0 B_1$	0.368	0.360	0.745	3.31	0.825	0.260
$S_0 B_2$	0.362	0.450	0.870	2.93	0.857	0.257
$S_0 B_3$	0.407	0.465	1.150	2.78	1.930	0.290
$S_1 B_0$	0.460	0.345	0.780	3.41	1.070	0.327
$S_1 B_1$	0.562	0.400	0.940	3.60	0.890	0.281
$S_1 B_2$	0.805	0.402	1.060	3.94	1.200	0.389
$S_1 B_3$	1.060	0.415	1.290	2.79	1.250	0.384
$S_2 B_0$	0.904	0.440	0.850	4.03	1.300	0.414
$S_2 B_1$	1.040	0.500	1.080	4.47	0.893	0.420
$S_2 B_2$	1.210	0.555	1.110	4.03	0.806	0.460
$S_2 B_3$	1.290	0.590	1.260	2.74	1.310	0.465
$S_3 B_0$	1.060	0.410	0.925	4.80	0.870	0.505
$S_3 B_1$	1.390	0.420	0.960	3.31	0.916	0.516
$S_3 B_2$	1.410	0.470	1.020	3.98	1.350	0.520
$S_3 B_3$	1.520	0.475	1.320	2.45	1.950	0.527
S_0	0.359	0.396	0.874	2.78	1.120	0.254
S_1	0.722	0.391	1.018	3.43	1.100	0.345
S_2	1.110	0.521	1.075	3.82	1.080	0.439
S_3	1.345	0.444	1.056	3.64	1.450	0.517
B_0	0.681	0.376	0.821	3.59	0.902	0.364
B_1	0.840	0.420	0.931	3.67	1.140	0.369
B_2	0.947	0.469	1.015	3.70	1.320	0.407
B_3	1.069	0.486	1.255	2.69	1.090	0.417
F-S	148.90**	120.11**	5.94**	3.38*	3.86*	10.20**
F-B	22.73**	27.05**	2.87^{NS}	4.17*	3.94*	3.80*
F-S.B	14.18**	12.82**	4.75**	2.63*	5.82**	2.84*
CD - S	0.154	0.0472	0.1320	0.833	0.305	0.239
CD - B.	0.154	0.0472	-	0.833	0.305	0.239
CD - S.B	0.307	0.0940	0.2640	1.67	0.610	0.477

Table 15 b. Nutrient concentration of bhusa at harvest of the second crop (%)

Treatments	N	P	K	Ca	Mg	S
$S_0 B_0$	0.402	0.369	0.700	1.96	0.778	0.209
$S_0 B_1$	0.415	0.430	0.750	3.25	0.875	0.215
$S_0 B_2$	0.419	0.455	0.875	3.30	1.15	0.283
$S_0 B_3$	0.440	0.465	0.900	2.90	0.845	0.287
$S_1 B_0$	0.503	0.512	0.790	3.36	0.650	0.312
$S_1 B_1$	0.520	0.528	1.170	3.30	0.835	0.320
$S_1 B_2$	0.525	0.563	1.230	3.45	1.235	0.346
$S_1 B_3$	0.560	0.598	1.210	3.05	1.235	0.389
$S_2 B_0$	0.789	0.660	0.905	4.3	0.715	0.420
$S_2 B_1$	0.792	0.682	1.110	2.25	0.675	0.439
$S_2 B_2$	0.803	0.690	1.200	3.15	1.305	0.450
$S_2 B_3$	0.815	0.592	1.250	2.30	1.320	0.472
$S_3 B_0$	1.050	0.525	0.925	3.35	0.770	0.510
$S_3 B_1$	1.085	0.540	1.150	3.15	1.120	0.545
$S_3 B_2$	1.182	0.575	1.370	3.70	1.305	0.549
$S_3 B_3$	1.250	0.655	1.480	2.85	1.075	0.562
S_0	0.419	0.430	0.806	2.85	0.911	0.249
S_1	0.527	0.550	1.100	3.29	0.989	0.342
S_2	0.799	0.656	1.116	3.00	1.001	0.445
S_3	1.142	0.574	1.232	3.26	1.02	0.542
B_0	0.686	0.517	0.830	3.24	0.668	0.363
B_1	0.703	0.545	1.045	2.99	0.886	0.380
B_2	0.732	0.571	1.169	3.40	1.248	0.407
B_3	0.766	0.578	1.210	2.78	1.119	0.428
F-S	20.90^{**}	2.88^{NS}	3.87^{*}	4.89^{*}	13.56^{**}	20.73^{**}
F-B	6.87^{**}	3.42^{*}	0.240^{NS}	8.37^{**}	12.11^{**}	16.46^{**}
F-S.B	6.57^{**}	3.03^{*}	0.638^{NS}	10.63^{**}	26.96^{**}	20.80^{**}
CD - S	0.2634	0.05785	0.3156	0.2873	0.1265	0.2150
CD - B.	0.2634	-	-	0.2873	0.1265	0.2150
CD - S.B	0.5268	0.1157	-	0.5747	0.2530	0.4299

by T_{15} (S_3B_{12}) and T_{14} (S_3B_1) all of which were on par. The lowest value of 0.301 per cent was shown by T_1 (S_0B_0) preceded by T_3 (S_0B_2) and T_2 (S_0B_1). This clearly indicates the positive influence of S in the N content of bhusa.

Among the different S levels, S_3 (30.0 kg S ha^{-1}) recorded the highest value of 1.345 per cent which was significantly superior to other levels of S followed by S_2. B_3 (7.5 kg B ha^{-1}) recorded the highest value of 1.069 per cent among the levels of B and was on par with B_2. The lowest values of 0.359 per cent and 0.681 per cent were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

In the second crop also it had been observed that the interaction of different levels of these nutrients had significant effect on the N content of the crop. T_{16} (S_3B_3) was superior to other treatments and was followed by T_{15} (S_3B_2). The values ranged between 0.402 per cent (T_1) and 1.25 per cent.

Significant effect of the different levels of S and B individually was also observed for this parameter. S_3 (30.0 kg S ha^{-1}) recorded the significantly highest value (1.142 %) followed by S_2 (15 kg S ha^{-1}) and S_1 (7.5 kg S ha^{-1}). S_0 (0 kg S ha^{-1}) showed the lowest value of 0.419 per cent. Among the levels of B, B_3 (7.5 kg B ha^{-1}) recorded the highest value of 0.766 per cent followed by B_2 (5 kg B ha^{-1}) and were on par. B_0 (0.0 kg B ha^{-1}) recorded the lowest value of 0.680 per cent.

4.2.4.1.2 Phosphorus

In the first crop, application of S and B significantly influenced the phosphorus content of sesame. The highest value of 0.590 per cent was recorded by T_{12} (S_2B_3) and was on par with T_{11} (S_2B_2). The lowest value was noted in T_1 (S_0B_0) as 0.310 per cent.

Regarding the individual effects of different levels of S and B, S_2 (15.0 kg S ha^{-1}) was the significantly superior level of S which recorded a value of 0.521 per cent followed by S_1. S_0 (0 kg S ha^{-1}) showed the lowest value of 0.396 per cent. Among the B levels B_3 (7.5 kg B ha^{-1}) showed the highest value of 0.486 per cent. B_0 (0.0 kg B ha^{-1}) recorded the lowest value of 0.376 per cent.

In the second crop, significant effect of the different levels of S and B was observed. The interaction between different levels of S and B was significant and S_2B_2 (T_{11}) recorded the highest value of 0.690. The lowest value of 0.369 per cent was recorded by T_1 (S_0B_0) which was significantly lower than the other treatment combinations.

As regard to the main effects of different levels of S and B, S_2 (15.0 kg S ha^{-1}) showed the superior value of 0.656 per cent followed by S_3. The lowest value of 0.430 per cent was shown by S_0. The effects of B were significant on the P content of sesame and the values ranged from 0.517 per cent and 0.578 per cent being recorded by B_0 (0.0 kg B ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively.

4.2.4.1.3 Potassium

Statistical analysis of the data revealed that the application of S and B had significant effect on the K content of sesame during the first crop. The interaction effect of S and B showed significant effect on the K content. T_{16} (S_3B_3) recorded the highest value of 1.320 per cent followed by T_{15} (S_3B_2) and all of were on par. The lowest value was shown by T_1 (S_0B_0) as 0.730 per cent which was preceded by T_2 (S_0B_1).

As regard to the individual effects of different levels of S and B, significance was observed with the levels of S only. S_2 (15 kg S ha^{-1}) recorded the highest value of 1.075 per cent and was followed by S_3 (30 kg S ha^{-1}). The highest value was shown by B_3 (7.5 kg S ha^{-1}) as 1.255 per cent. The lowest values of 0.874 and 0.821 per cent were shown by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

Analysis of the data pertaining to the K content of the second crop showed that the interaction between S and B could not produce any significant effect on the parameter. The values were in the range 0.70 per cent and 1.48 per cent recorded by T_1 (S_0B_0) and T_{16} (S_3B_3).

The individual effects of S were significant for the K content of bhusa as in the case of the first crop. S_3 (30 kg S ha^{-1}) recorded the highest value of 1.232 per cent and was on par with S_2 (15.0 kg S ha^{-1}). The lowest value of 0.806 per cent was observed in S_0. Among the different levels of B, the highest value of 1.210 per cent was shown by B_3 (7.5 kg B ha^{-1}) and the lowest value of 0.830 per cent was observed in B_0 (0.0 kg B ha^{-1}).

4.2.4.1.4 Calcium

The Ca content of sesame bhusa was significantly influenced by the application of different levels of S and B. Significant interaction of S and B was noticed for the interaction of different levels and the highest value of 4.8 per cent was recorded by T_{13} (S_3B_0) followed by T_{10} (S_2B_1) and T_9 (S_2B_0) all of which were on par. The lowest value of 2.11 per cent was shown by T_1 (S_0B_0).

As regard to the individual effects of different levels of S and B a decreasing trend with increasing levels of B was observed. S_2 (15.0 kg S ha^{-1}) recorded the highest value of 3.82 per cent followed by S_3 (30.0 kg S ha^{-1}) and S_1 (7.5 kg S ha^{-1}) and these were on par. The lowest value of 2.78 per cent was recorded by S_0. Among the levels of B, the highest value of 3.70 per cent was shown by B_2 (5.0 kg B ha^{-1}) and was on par with B_1 (2.5 kg B ha^{-1}) and B_0 (0.0 kg B ha^{-1}). The lowest value of 2.69 per cent was shown by B_3 (7.5 kg B ha^{-1}).

For the second crop, the trend was the same as that of the first crop. The interaction between S and B were significant and the values ranged from 1.96 to 4.3 per cent recorded by T_1 (S_0B_0) and T_9 (S_2B_0) respectively. T_9 (S_2B_0) was significantly superior to others.

The levels of S and B showed significant effect on the Ca content of bhusa. S_1 (7.5 kg S ha^{-1}) recorded the highest value of 3.29 per cent and was on par with S_3 (30.0 kg S ha^{-1}). The lowest value of 2.85 per cent was shown by S_0 (0 kg S ha^{-1}). Among the B levels B_2 (5.0 kg B ha^{-1}) recorded the highest value of 3.4 per cent and the lowest value of 2.78 per cent was shown by B_3 (7.5 kg B ha^{-1}).

4.2.4.1.5 Magnesium

Significant effect of the interaction of S and B was noticed in the Mg content of bhusa. The values ranged from 0.806 (T_{11}) to 1.95 (T_{16}).

S and B levels individually also had significant effect upon the Mg content of sesame. The highest value of 1.45 per cent among the different levels was recorded by S_3. The lowest value of 1.08 per cent was shown by S_2. B_2 (5.0 kg B ha^{-1}) recorded the highest value of 1.32 per cent among the different levels of B and the lowest value of 0.902 per cent was recorded by B_0 (0.0 kg B ha^{-1}).

Data on the Mg content of the bhusa of the second crop shows the significant influence of different levels of S and B individually and its interaction with each other. T_{12} (S_2B_3) recorded the highest value of 1.320 per cent. The lowest value was shown by T_{11} (0.675%).

With regard to the individual effects of S and B, S_3 (30.0 kg S ha^{-1}) was the superior level which recorded a value of 1.02 per cent followed by S_2 (1.00%). The lowest value was shown by S_0 (0.911%). Among the B levels, B_2 (5 kg B ha^{-1}) recorded the highest value of 1.248 per cent followed by B_3 (7.5 kg B ha^{-1}). The lowest value of 0.668 per cent was recorded by B_0.

4.2.4.1.6 Sulphur

In the first crop, significant interaction was noticed between the different levels of S and B. The values ranged from 0.210 per cent to 0.527 per cent produced by T_{16} (S_3B_3) and T_1 (S_0B_0) respectively. T_{16} (S_3B_3) was on par with T_{15} (S_3B_2).

The levels of S individually had significant effect on the S content of bhusa. S_3 (30.0 kg S ha^{-1}) showed the highest value of 0.517 per cent which was on par with S_2. The lowest value of 0.254 per cent was recorded by S_0. Among the levels of B, the highest value of 0.417 per cent was shown by B_3. B_0 (0.0 kg B ha^{-1}) showed the lowest value of 0.364 per cent.

A similar trend as shown by the first crop was revealed in the second year also for the S content. Significant effect of the interaction between different levels of S and B was observed and the values ranged from 0.209 per cent (T_1) to 0.562 per cent (T_{16}). T_{16} (S_3B_3) was on par with T_{15} (S_3B_1) both of which received S @ 30 kg ha^{-1}.

Considering the individual effects of S and B, as the level of S applied increased, its content in bhusa also gradually increased. S_3 (30.0 kg S ha^{-1}) was the significantly superior level which recorded a value of 0.542 per cent followed by S_2. The lowest value of 0.249 per cent was shown by S_0. The levels of B also showed a positive trend with the increasing levels and the values ranged between 0.363 per cent and 0.428 per cent being recorded by B_0 (0.0 kg B ha^{-1}) and B_3 (7.5 kg B ha^{-1}).

4.2.4.1.7 ***Boron*** (Table 16 a and 16 b)

It is evident from the data that the treatment effects were highly significant for the total B content of bhusa for both the crops and the data analysis indicated the positive influence of applied B and S on the B content of bhusa.

In the first crop, among the interaction effects, T_{16} (S_3B_3) which received both the nutrients at highest level registered the highest value which was significantly superior to all other treatments. This was followed by T_6 (S_1B_1) and T_7 (S_1B_2) and were on par with each other. T_1 (S_0B_0) registered the lowest value and was preceded by T_2 (S_0B_1). The values ranged from 5.75 mg kg^{-1} to 26.75 mg kg^{-1}.

Among the individual effects of S and B, S_3 (30 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the significantly superior levels and their subsequent lower levels followed them. The values recorded were 18.33 mg kg^{-1} and 21.03 mg kg^{-1} respectively. The lowest values of 10.01 mg kg^{-1} and 9.47 mg kg^{-1} were recorded by S_0 and B_0 respectively.

Perusal of the data pertaining to the B of the second crop showed that the interaction between different levels of S and B was significant. T_{16} (S_3B_{23}) recorded the significantly superior value of 22.60mg kg^{-1} followed by T_8 (S_2B_3).

Table 16 a. Micronutrient concentration of bhusa at harvest of the first crop(mg kg^{-1})

Treatments	B	Fe	Mn	Cu	Zn
$S_0 B_0$	5.75	105.00	30.50	8.00	23.00
$S_0 B_1$	7.69	150.00	55.00	10.50	21.50
$S_0 B_2$	11.85	229.00	41.00	12.00	17.00
$S_0 B_3$	14.75	227.00	50.00	12.00	17.00
$S_1 B_0$	12.32	114.00	33.50	16.00	18.00
$S_1 B_1$	11.61	141.00	53.00	11.00	21.00
$S_1 B_2$	19.71	281.50	27.00	10.00	20.50
$S_1 B_3$	21.78	173.50	54.00	12.50	16.00
$S_2 B_0$	11.28	110.00	47.00	12.00	36.00
$S_2 B_1$	13.27	166.00	57.00	16.00	15.50
$S_2 B_2$	16.08	210.50	70.00	13.00	25.50
$S_2 B_3$	20.85	168.50	66.50	11.00	34.50
$S_3 B_0$	13.53	142.50	68.50	13.50	23.00
$S_3 B_1$	16.75	140.00	58.50	15.00	12.00
$S_3 B_2$	21.28	168.50	45.00	11.20	17.00
$S_3 B_3$	26.75	214.00	22.50	16.50	36.00
S_0	10.01	177.75	51.25	10.63	19.63
S_1	16.36	202.50	41.88	14.13	18.88
S_2	15.37	163.75	60.13	13.00	27.88
S_3	18.33	211.25	48.63	12.93	22.00
B_0	9.47	117.90	52.00	12.38	25.00
B_1	12.33	174.00	55.88	13.13	17.50
B_2	17.23	222.38	45.75	11.55	20.00
B_3	21.03	240.75	48.25	13.63	25.88
F-S	26.39**	66.72**	40.22**	102.37**	19.71**
F-B	9.01**	226.24**	7.69**	121.43**	19.06**
F-S.B	28.15**	81.38**	3.2*	100.09**	14.58**
CD - S	1.65	10.84	5.86	1.26	2.77
CD - B.	1.65	10.84	5.86	1.26	2.77
CD - S.B	3.31	21.68	11.72	2.52	5.54

Table 16 b.Micronutrient concentration of bhusa at harvest of the second crop (mg kg^{-1})

Treatments	B	Fe	Mn	Cu	Zn
$S_0 B_0$	3.16	136.50	61.0	6.00	24.50
$S_0 B_1$	4.93	146.50	53.50	9.50	22.50
$S_0 B_2$	9.59	186.00	43.00	9.25	20.50
$S_0 B_3$	13.02	188.50	52.00	9.60	16.50
$S_1 B_0$	5.20	109.00	35.50	14.25	16.50
$S_1 B_1$	8.84	205.00	57.00	12.00	23.50
$S_1 B_2$	14.74	298.00	27.00	11.65	20.50
$S_1 B_3$	20.81	163.50	43.50	14.50	16.00
$S_2 B_0$	6.83	108.00	66.50	11.00	16.00
$S_2 B_1$	12.55	152.50	35.00	14.00	37.50
$S_2 B_2$	13.44	190.50	72.50	13.50	24.00
$S_2 B_3$	19.84	158.50	63.50	10.60	34.50
$S_3 B_0$	9.32	141.00	76.50	12.50	23.00
$S_3 B_1$	14.07	103.50	72.50	14.50	13.50
$S_3 B_2$	19.88	168.50	44.50	12.40	18.00
$S_3 B_3$	22.60	293.50	47.50	12.50	37.50
S_0	7.68	164.38	52.38	8.59	21.00
S_1	12.40	193.88	40.75	13.10	19.13
S_2	13.17	152.38	59.30	12.28	28.00
S_3	16.47	176.63	60.50	12.98	23.00
B_0	6.13	123.63	59.80	10.94	25.38
B_1	10.10	151.88	54.50	12.50	18.88
B_2	14.41	210.75	46.75	11.70	20.75
B_3	19.07	201.00	51.63	11.80	26.13
F-S	3.33*	197.59**	27.94**	2.30^{NS}	44.41**
F-B	5.93**	1065.45**	7.57**	2.98^{NS}	37.79**
F-S.B	3.13*	430.90**	19.54**	1.65^{NS}	45.74**
CD - S	3.910	3.802	395.14	-	1.728
CD - B.	3.910	3.802	5.139	-	1.728
CD - S.B	7.821	7.604	10.279	-	3.457

The lowest value (3.16 mg kg^{-1}) was recorded by T_1 (S_0B_0) preceded by T_2 (S_0B_1) which were on par..

In the second crop also the trend was pointing towards the positive influence of increasing B levels on its content in bhusa. Application of different levels of S had significant effect on the B content of bhusa. S_3 (30.0 kg S ha^{-1}) recorded the maximum value of 16.47 mg kg^{-1} and was on par with S_2 (15.0 kg S ha^{-1}) and S_1. The lowest value of 7.68 mg kg^{-1} was recorded by S_0. Among the different levels of B, the highest value of 19.07 mg kg^{-1} was recorded by B_3 (7.5 kg B ha^{-1}) which was significantly superior to the other levels. The lowest value of 6.13 mg kg^{-1} was recorded by B_0 (0.0 kg B ha^{-1}).

4.2.4.1.8 Iron

The micronutrient content of the plants were positively influenced by the application treatments either alone or in combination with each other at varying levels as reflected in the analytical results presented in Table .

T_7 (S_1B_2) recorded the significantly superior value of 281.50 mg kg^{-1}. The lowest value of 105.00 mg kg^{-1} was shown by T_1, and was on par with T_9 (S_2B_0) and T_5 (S_1B_0).

Increasing levels of S and B significantly influenced the Fe content of bhusa with S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recording the maximum values of 211.25 mg kg^{-1} and 240.75 mg kg^{-1} respectively. The lowest values of 163.75 ppm and 117.90 mg kg^{-1} were recorded by S_2 (15 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

The interaction between different levels of S and B showed significant effect on the Fe content in bhusa and the highest value of 298.00 mg $kg^{-1}$was shown by T_7 (S_1B_2) followed by T_{16} (293.50 mg kg^{-1}) and they were on par with each other. The lowest value of 103.50 mg $kg^{-1}$was shown by T_{14} (S_3B_1) preceded by T_9 (S_2B_0).

Application of different levels of S and B had a significant effect on the Fe content of bhusa. S_1 (7.5 kg S ha^{-1}) recorded the significantly highest value of

193.88 mg kg^{-1} followed by S_3 (176.63 mg S kg^{-1}). The lowest value of 152.38 mg kg^{-1}was shown by S_2. All the levels were significantly higher than S_2. Among the levels of B, it has been found that B_2 (5.0 kg B ha^{-1}) was the significantly superior level for B and showed a value of 210.75 mg kg^{-1} followed by B_3. The significantly lowest value of 123.63 mg kg^{-1} was recorded by B_0 (0.0 kg B ha^{-1}).

4.2.4.1.9 Manganese

The various treatment combinations tried had significant effect on the Mn content of the bhusa of the first crop. The interaction of S and B was also significant on the Mn content of bhusa and the highest value of 70.0 mg kg^{-1} was shown by T_{11} (S_2B_2) followed by T_{13} (S_3B_0) which were on par and the lowest value by T_{16} (S_3B_3) as 22.5 mg kg^{-1} preceded by T_7 (S_1B_2).

Regarding the main effects of different levels of S and B, S_2 (15.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) registered the maximum values 60.13 mg kg^{-1} and 55.88 mg kg^{-1}respectively among the levels of S and B. The lowest values of 41.88 mg kg^{-1}and 45.75 mg kg^{-1} were shown by S_1 (7.5 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively.

Analysis of the data pertaining to the second crop also showed significant effect of the interaction between different levels of S and B. The values ranged from 27.0 to 76.5 mg kg^{-1}recorded by T_7 (S_1B_2) and T_{13} (S_3B_0) respectively.

Considering the individual effects, application of different levels of these nutrients also registered significant influence on the parameter. The highest value 60.5 mg kg^{-1} was shown by S_3 (30.0 kg S ha^{-1}) which was on par with S_2 (15.0 kg S ha^{-1}) and the lowest value of 40.75 mg kg^{-1} was produced by S_1. Among the levels of B, B_0 (0.0 kg B ha^{-1}) recorded the highest value of 59.8 mg kg^{-1} and was on par with B_1 (2.5 kg B ha^{-1}). The lowest value of 46.75 mg kg^{-1} was recorded by B_2 (5.0 kg B ha^{-1}).

4.2.4.1.10 Copper

In the first crop, the copper content of bhusa of the first crop was significantly influenced by the treatments. The interaction of different levels of S and B were also significant for the Mn content of bhusa and the highest value of 16.50 mg kg^{-1} was recorded by T_{16} (S_3B_3) which was superior to all the other levels. The lowest value of 8 mg kg^{-1} was recorded by T_1 (S_0B_0).

As for the individual effects of different levels of S and B, S_1 (7.5 kg S ha^{-1}) was the superior level for S followed by S_2 (15 kg S ha^{-1}) and recorded the values of 14.13 mg $kg^{-1}$and 13.00 mg kg^{-1} respectively. The lowest value of 10.63 mg $kg^{-1}$was shown by S_0. B_3 (7.5 kg B ha^{-1}) recorded the superior level followed by B_1 (2.5 kg B ha^{-1}) and the values were13.63 mg kg^{-1} and 13.13 mg kg^{-1} respectively. The lowest value of 11.55 mg $kg^{-1}$was shown by B_2.

It is obvious from the data presented in table that the interaction between different levels of S and B were not significant with regard to the Cu content of the second crop. The highest value of 14.50 mg kg^{-1} was recorded by S_1B_3 (T_8). The lowest value of 6.00 mg kg^{-1} was shown by T_1 (S_0B_0).

The different levels of S and B individually also did not register any significant influence on the Cu content of the crop. S_3 (7.5 kg S ha^{-1}) recorded the highest value of 12.98 mg kg^{-1}. S_0 (0 kg S ha^{-1}) recorded the lowest value of 8.59 mg kg^{-1}. The positive influence was also reflected on the effect of B levels and the highest value of 12.50 mg kg^{-1} was shown by B_1 (2.5 kg B ha^{-1}). The lowest value of 10.94 mg kg^{-1} was shown by B_0 (0 kg B ha^{-1}).

4.2.4.1.11 Zinc

Application of different levels of S and B had significant effect on the Zn content in bhusa of the first crop. Both T_9 (S_2B_0) and T_{16} (S_3B_3) registered the highest value of 36 mg kg^{-1} followed by T_{12} (S_2B_3) and T_{11} (S_2B_2). The lowest value of 12 mg kg^{-1} was shown by T_{14} (S_3B_1).

Among the individual effects, S_2 (27.88 mg kg^{-1}) and B_3 (25.88 mg kg^{-1}) recorded the highest values among the different levels of S and B. The lowest values of 18.88 mg $kg^{-1}$and 17.50 mg kg^{-1} were shown S_1 (7.5 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively.

For the second crop, as in the case of other micronutrients, the treatment effects were highly significant for the Zn content of bhusa. The interaction effect was highly significant and the values ranged from 13.50 mg kg^{-1} to 37.50 mg kg^{-1} recorded by T_{14} (S_3B_1) and T_{16} (S_3B_3) respectively. T_{14} (S_3B_1) was preceded by T_8 (S_1B_3).

With regard to the individual effects of different levels of S and B, S_2 (15.0 kg ha^{-1}) was the significantly superior S level (28.00 mg kg^{-1}) followed by S_3. The lowest value of 19.13 ppm was shown by S_1. Among the levels of B, B_3 (7.5 kg B ha^{-1}) recorded the highest value of 26.13 mg plant^{-1} which was significantly higher than others and the lowest value of 18.88 mg kg^{-1} was recorded by B_1 (2.5 kg B ha^{-1}).

4.2.4.2 Grain (Table 17 a and 17 b)

4.2.4.2.1 Nitrogen

In the first crop, the N content of grain was significantly influenced by the application of different levels of S and B. T_{16} (S_3B_3) recorded the highest value of 2.80 per cent followed by T_{15} (2.79%) and they were on par with each other. The lowest value of 1.95 per cent was recorded by T_1 (S_0B_0) which was significantly lower than all the other treatments.

Considering the individual effects, S_3 (30.0 kg S ha^{-1}) recorded the significantly superior value of 2.77 per cent followed by S_2 (2.32 %). Among the levels of B, B_3 (7.5 kg B ha^{-1}) recorded the highest value of 2.49 per cent followed by B_2 (2.39%). The lowest values of 2.06 and 2.22 per cent were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

In the second crop, perusal of the data showed that the interaction between different levels of S and B were significant as in the case of the first crop. The highest value (2.89%) was recorded by T_{16} (S_3B_3) followed by T_{14} (2.82%) and were on par with each other. The lowest value of 2.02 per cent was recorded by T_1 (S_0B_0).

With regard to the main effects of different levels of S and B, significant effect was observed on the parameter. S_3 (30.0 kg S ha^{-1}) was the superior S level which recorded a value of 2.81 per cent and was followed by S_2 (2.56%) and were on par. The lowest value of 2.16 per cent was shown by S_0.Among the different levels of B, B_3 (7.5 kg B ha^{-1}) recorded the highest value of 2.54 per cent and was on par with B_1. The lowest value of 2.41 per cent was shown by B_0 (0.0 kg B ha^{-1}).

4.2.4.2.2 Phosphorus

On critical examination of the data pertaining to the first crop, only the levels of B and their interaction with S had significant effect on the P content of grain. The interaction of different levels of S and B was significant for the P content of grain and the values ranged from 0.156 per cent to 0.484 per cent being shown by T_1 (S_0B_0) and T_{16} (S_3B_3) respectively.

Regarding the main effects of different levels of S and B, the highest value (0.413%) among the different levels of S was shown by S_3. Among the levels of B, B_3 (7.5 kg B ha^{-1}) recorded the highest value of 0.454 per cent which was on par with B_2 (0.388%) and the lowest value of 0.238 per cent was shown by B_0 (0 kg B ha^{-1})

In the second crop, it has been found that application of different levels of S and B had significant effect on the P content of grain. The interaction of S and B were highly significant. T_{16} (S_3B_3) recorded the highest value of 0.473 per cent and was on par with T_{15} (S_3B_2). The lowest value of 0.273 per cent was recorded by T_1 (S_0B_0).

Considering the main effects of different levels of S and B, S_3 (30.0 kg S ha^{-1}) recorded the highest value of 0.458 per cent which was significantly superior to the other levels. Among the levels of B, B_3 (7.5 kg B ha^{-1}) recorded the highest value of 0.385 per cent and B_0 (0.0 kg B ha^{-1}) recorded the lowest value 0f 0.342 per cent.

Table 17a. Nutrient concentration of grain at harvest of the first crop (%)

Treatments	N	P	K	Ca (%)	Mg	S
$S_0 B_0$	1.95	0.156	0.350	0.888	0.209	0.173
$S_0 B_1$	2.05	0.175	0.485	1.640	0.279	0.177
$S_0 B_2$	2.10	0.283	0.500	1.280	0.185	0.205
$S_0 B_3$	2.13	0.442	0.535	0.893	0.232	0.210
$S_1 B_0$	2.11	0.204	0.475	1.340	0.253	0.306
$S_1 B_1$	2.25	0.223	0.490	1.320	0.190	0.394
$S_1 B_2$	2.31	0.412	0.505	1.610	0.232	0.424
$S_1 B_3$	2.49	0.437	0.505	1.340	0.295	0.482
$S_2 B_0$	2.10	0.260	0.475	1.340	0.194	0.399
$S_2 B_1$	2.28	0.355	0.490	1.560	0.225	0.399
$S_2 B_2$	2.37	0.442	0.519	1.670	0.230	0.420
$S_2 B_3$	2.52	0.453	0.540	0.911	0.131	0.480
$S_3 B_0$	2.73	0.332	0.430	1.270	0.114	0.391
$S_3 B_1$	2.76	0.421	0.520	1.430	0.206	0.443
$S_3 B_2$	2.79	0.416	0.530	1.630	0.176	0.509
$S_3 B_3$	2.80	0.484	0.545	1.020	0.233	0.532
S_0	2.06	0.264	0.468	1.180	0.201	0.191
S_1	2.29	0.319	0.494	1.400	0.242	0.402
S_2	2.32	0.378	0.5060	1.360	0.195	0.425
S_3	2.77	0.413	0.5062	1.340	0.182	0.469
B_0	2.22	0.238	0.433	1.210	0.192	0.317
B_1	2.34	0.294	0.496	1.490	0.225	0.353
B_2	2.39	0.388	0.514	1.540	0.206	0.389
B_3	2.49	0.454	0.531	1.040	0.198	0.426
F-S	12.78**	1.46^{NS}	10.68**	4.88*	0.590^{NS}	4.04*
F-B	4.18*	7.67**	13.89**	4.80*	0.178^{NS}	3.82*
F-S.B	9.16**	4.91**	8.67**	2.65*	0.687^{NS}	2.90*
CD - S	0.147	0.0764	0.0554	0.480	-	0.0670
CD - B.	0.147	-	0.0544	0.480	-	0.0670
CD - S.B	0.294	0.1528	0.1110	0.962	-	0.1340

Table 17 b. Nutrient concentration of grain at harvest of the second crop (%)

Treatments	N	P	K	Ca	Mg	S
$S_0 B_0$	2.02	0.273	0.315	0.835	0.197	0.236
$S_0 B_1$	2.17	0.298	0.470	1.580	0.27	0.241
$S_0 B_2$	2.23	0.312	0.475	1.540	0.225	0.253
$S_0 B_3$	2.20	0.315	0.595	0.909	0.150	0.260
$S_1 B_0$	2.36	0.301	0.500	1.320	0.295	0.357
$S_1 B_1$	2.38	0.310	0.508	1.200	0.200	0.402
$S_1 B_2$	2.46	0.320	0.512	1.580	0.210	0.418
$S_1 B_3$	2.50	0.340	0.520	0.785	0.265	0.420
$S_2 B_0$	2.49	0.365	0.492	1.410	0.260	0.439
$S_2 B_1$	2.68	0.363	0.501	1.530	0.218	0.473
$S_2 B_2$	2.48	0.396	0.510	1.690	0.260	0.437
$S_2 B_3$	2.58	0.410	0.520	0.920	0.145	0.424
$S_3 B_0$	2.75	0.428	0.522	1.220	0.135	0.456
$S_3 B_1$	2.82	0.459	0.528	1.425	0.170	0.492
$S_3 B_2$	2.77	0.471	0.533	1.625	0.205	0.504
$S_3 B_3$	2.89	0.473	0.555	1.070	0.265	0.567
S_0	2.16	0.299	0.464	1.215	0.211	0.248
S_1	2.40	0.318	0.510	1.218	0.243	0.399
S_2	2.56	0.384	0.506	1.390	0.221	0.443
S_3	2.81	0.458	0.535	1.330	0.194	0.505
B_0	2.41	0.342	0.457	1.193	0.222	0.372
B_1	2.51	0.358	0.502	1.432	0.214	0.402
B_2	2.46	0.375	0.508	1.605	0.225	0.404
B_3	2.54	0.385	0.548	0.920	0.206	0.418
F-S	6.57**	5.41*	19.23**	12.05**	1.68^{NS}	33.15**
F-B	3.33*	18.06**	12.79**	23.05**	0.283^{NS}	19.67**
F-S.B	12.33**	12.41**	6.52**	14.47**	3.49*	31.63**
CD - S	0.4486	0.05123	0.0437	0.1157	-	0.0515
CD - B.	0.4486	0.05123	0.0437	0.1157	-	0.0515
CD - S.B	0.8973	0.1025	0.0874	0.2314	0.0945	0.1029

4.2.4.2.3 Potassium

Statistical analysis of the data showed that the application of S and B were highly significant for the K content of grain. The interaction of S and B were highly significant for the K content of grain and the values varied from 0.350 per cent to 0.545 per cent recorded by $T_{16}(S_3B_3)$ and T_1 (S_0B_0) respectively.

Among the different levels of S, S_3 (30.0 kg S ha^{-1}) recorded the highest value of 0.5062 per cent which was on par with S_2 (15.0 kg S ha^{-1}). B_3 (7.5 kg B ha^{-1}) was the superior level among the B levels and registered a value of 0.531 per cent followed by B_2 (0.514%). The lowest values of 0.468 per cent and 0.433 per cent were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

Perusal of the data for the second crop indicated that the treatments have a significant effect on K content and the trend was the same as that of the first crop. The interaction of different levels of S and B has also been found to be significant. The values ranged from 0.315 per cent to 0.555 per cent recorded by T_1 (S_0B_0) and T_{16} (S_3B_3) respectively.

The levels of S and B individually had also significant effect on this parameter. The highest value of 0.535 per cent was recorded by S_3 (30.0 kg S ha^{-1}) and was on par with S_1. The lowest value of 0.464 per cent was shown by S_0. Among the levels of B, B_3 (7.5 kg B ha^{-1}) recorded significantly highest value of 0.548 per cent. The lowest value of 0.457 per cent was observed with B_0 (0.0 B kg ha^{-1}).

4.2.4.2.4 Calcium

In the first crop it is evident from the data that the Ca content of the grain was significantly influenced by the application of S and B at different levels. The interaction of S and B levels was significant for the Ca content and the highest value of 1.670 per cent was shown by T_{11} (S_2B_2) which was on par with T_2 (S_0B_1) and T_{15} (S_3B_2). The lowest value of 0.888 per cent was recorded by T_1 (S_0B_0).

Perusal of the data indicated that as the level of B increased, a gradual decrease in the calcium content was observed. Trend was same as in the case of bhusa. Among the different levels of S and B, the highest values of 1.40 per cent and 1.54 per cent were recorded by S_1 (7.5 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively. The lowest values of 1.18 per cent and 1.04 per cent were recorded by S_0 (0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively.

On critical examination of the data (Table) it could be inferred that the interaction of different levels of S and B was significant on the Ca content of the grain. The highest value of 1.69 per cent was shown by T_{11} (S_2B_2) followed by T_{15} (S_3B_2) which were on par. The lowest value of 0.835 per cent was for T_1 (S_0B_0).

As for the main effect of different levels of S and B, the trend was same as in the case of first crop. Significant influence of different levels of S and B with the Ca content of grain had been observed with. S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) recorded the highest values of 1.390 per cent and 1.605 per cent respectively. The lowest value was observed with S_0 (1.215 %) and B_3 (0.920 %).

4.2.4.2.5 Magnesium

It is explicit from the data pertaining to the first crop that Mg content of grain was not significantly influenced by the application of S and B. The interaction effect of different levels of S and B was not significant for the Mg content. However, T_8 (S_1B_3) recorded the highest value of 0.295 per cent followed by T_2 (S_0B_1) and the lowest value of 0.114 per cent was recorded by T_{13} (S_3B_0).

Among the individual effects, levels of S and B, S_1 (7.5 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) recorded the highest values of 0.242 per cent and 0.225 per cent respectively. The lowest values of 0.182 and 0.192 was shown by S_3 (30.0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

The interaction of S and B were significant for the Mg content in the case of the second crop. The highest value of 0.295 per cent was shown by T_5 (S_1B_0) and was on par with T_2 (S_0B_1), T_8 (S_1B_3) and T_{16} (S_3B_3). The lowest value of 0.135 per cent was recorded by T_{13} (S_3B_0).

Regarding the individual effects of S and B, their levels had no significant effect upon the Mg content. Among the levels of S and B, S_1 (0.243%) and B_2 (0.225%) recorded the highest values. The lowest values of 0.194 per cent and 0.206 per cent were shown by S_3 (30.0 kg ha^{-1}) and B_3 (7.5 kg ha^{-1}) respectively.

4.2.4.2.6 Sulphur

In the first crop, the S content of the grain was significantly influenced by the application of S and B. The highest value of 0.532 per cent was recorded by T_{16} (S_3B_3) followed by T_{15} (S_3B_2). The lowest value of 0.173 per cent was recorded by T_1 (S_0B_0).

With regard to the individual effect of S and B, the trend showed that increasing levels of these nutrients had a significant effect on the S content in the grain. Among the different levels, S_3 (30.0 kg S ha^{-1}) recorded the highest value of 0.469 per cent followed by S_2 (15.0 kg S ha^{-1}) and they were on par. B_3 (7.5 kg B ha^{-1}) recorded the highest value of 0.426 per cent. The lowest values of 0.191 per cent and 0.317 per cent was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

In the second crop, the application of treatments significantly influenced the S content of the grain. Perusal of the data found significant influence of the interaction of S and B levels on the S content. T_{16} (S_3B_3) recorded the highest value of 0.567 per cent which was on par with T_{15} (0.504%). The lowest value was recorded by T_1 (0.236%).

The levels of S and B individually also significantly influenced the S content of grain. Increasing level of S applied showed an increasing trend for the S content of the grain and S_3 (30.0 kg S ha^{-1}) recorded a maximum value of 0.505 per cent followed by S_2 (0.443%) and were on par. The same trend was noticed for the different levels of B. B_3 (7.5 kg B ha^{-1}) recorded the highest value of 0.418 per cent followed by B_2 (5.0 kg B ha^{-1}) and B_1 (2.5 kg B ha^{-1}). The lowest value of 0.248 and 0.372 per cent was recorded by S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.4.2.7 Boron (Table 18 a and 18 b)

Application of different levels of S and B and their interaction significantly influenced the B concentration of grain in both the crops. The interaction of different levels of S and B also significantly influenced the B content and the highest value of and the highest value of 1.43 mg kg^{-1} was produced by T_8 (S_1B_3) which was on par with T_{16} (S_3B_3) and T_{15} (S_3B_2). T_1 (S_0B_0) showed the lowest value of 0.275 mg kg^{-1}.

Increasing levels of B significantly increased the B content of the grain. Among the levels of the nutrients, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 1.10 mg $kg^{-1}$and 1.07 mg kg^{-1} respectively and were followed by their subsequent lower levels. S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) recorded the lowest values of 0.500 mg $kg^{-1}$and 0.457 mg kg^{-1} respectively.

In the case of the second crop, the effects of different levels of S and B and their interaction were highly significant. It has been found that the interaction between different levels of S and B was highly significant and the values ranged from 0.275 mg kg^{-1} to 1.95 mg kg^{-1} being registered by T_1 (S_0B_0) and T_{16} (S_3B_3) respectively. T_{16} (S_3B_3) was the significantly superior level and was followed by T_{15} (S_3B_2) which received S at the highest level of 30 kg ha^{-1}.

Among the levels of S, S_3 (30.0 kg S ha^{-1}) recorded the highest value of 1.43 mg kg^{-1} followed by S_2 (0.90 mg kg^{-1}). The same trend was noticed with the levels of B such that increase in the level of applied B increased its content in grain. The highest value of 1.29 mg kg^{-1} was recorded by B_3 (7.5 kg B ha^{-1}) and was on par with B_2 (5.0 kg B ha^{-1}) and B_2. The lowest values among the different levels were shown by S_0 (0.548) and B_0 (0.608).

4.2.4.2.8 Iron

Application of different levels of S and B had a significant effect on the content of Fe in grain of the first crop. It has been statistically observed that the interaction of these nutrients have a significant effect on the Fe content of grain. The highest value was 254.00 mg kg^{-1}recorded by T_{11} (S_2B_2) and was

Table 18a. Micronutrient concentration of grain at harvest of the first crop (mg kg^{-1})

Treatments	Boron	Fe	Mn	Cu	Zn
$S_0 B_0$	0.275	95.50	11.50	16.0	34.00
$S_0 B_1$	0.425	106.50	27.00	16.0	35.00
$S_0 B_2$	0.625	148.50	18.00	21.0	39.00
$S_0 B_3$	0.675	55.50	26.50	20.0	39.00
$S_1 B_0$	0.363	65.50	14.50	21.0	35.50
$S_1 B_1$	0.400	117.00	24.00	18.5	43.00
$S_1 B_2$	0.475	85.50	17.00	20.5	34.00
$S_1 B_3$	1.430	254.00	31.00	27.0	46.00
$S_2 B_0$	0.500	175.00	31.00	23.0	47.00
$S_2 B_1$	0.725	162.50	33.00	24.0	43.50
$S_2 B_2$	0.935	254.00	51.00	37.5	40.00
$S_2 B_3$	1.080	139.00	18.00	17.0	42.50
$S_3 B_0$	0.688	171.00	18.00	22.0	43.00
$S_3 B_1$	1.210	108.00	28.00	21.5	47.00
$S_3 B_2$	1.230	85.50	13.00	17.5	40.50
$S_3 B_3$	1.280	168.00	14.50	18.5	49.50
S_0	0.500	101.50	20.75	18.25	36.75
S_1	0.666	130.50	21.63	19.88	39.63
S_2	0.809	182.63	33.25	21.75	43.25
S_3	1.100	133.13	18.38	25.38	45.00
B_0	0.457	126.75	18.75	20.50	39.88
B_1	0.690	123.50	28.00	20.00	42.13
B_2	0.816	143.38	24.75	24.13	38.75
B_3	1.12 0	154.13	22.50	20.63	44.25
F-S	16.26**	6215.57**	377.98**	29.42*	16.46**
F-B	11.81**	1135.91**	18.31**	6.63**	7.99**
F-S.B	11.02**	5576.62**	201.24**	32.39**	3.87**
CD - S	0.1670	1.290	1.080	1.530	2.740
CD - B.	0.1670	1.290	1.080	1.530	2.740
CD - S.B	0.3340	2.580	2.160	3.060	5.480

Table 18 b Micronutrient concentration of grain at harvest of the second crop (mg kg^{-1})

Treatments	B	Fe	Mn	Cu	Zn
$S_0 B_0$	0.275	93.00	14.00	21.00	35.50
$S_0 B_1$	0.525	104.00	25.50	17.50	35.50
$S_0 B_2$	0.625	144.00	17.00	21.500	36.00
$S_0 B_3$	1.040	52.50	25.50	21.00	37.00
$S_1 B_0$	0.325	65.00	15.00	22.00	37.00
$S_1 B_1$	0.365	116.00	14.50	20.50	44.00
$S_1 B_2$	0.525	83.00	16.50	17.00	37.00
$S_1 B_3$	0.975	254.00	31.00	26.50	50.000
$S_2 B_0$	0.650	176.50	32.00	25.00	45.50
$S_2 B_1$	0.725	167.50	34.00	26.00	44.50
$S_2 B_2$	1.030	256.50	52.00	37.00	41.00
$S_2 B_3$	1.200	142.00	17.50	18.50	50.50
$S_3 B_0$	1.180	175.50	19.00	24.00	42.00
$S_3 B_1$	1.200	113.50	27.50	22.50	49.00
$S_3 B_2$	1.400	84.00	15.00	17.50	40.50
$S_3 B_3$	1.950	170.50	23.50	19.50	41.00
S_0	0.548	98.38	20.50	19.25	36.00
S_1	0.616	129.50	19.25	22.50	42.00
S_2	0.901	185.63	33.88	26.63	45.38
S_3	1.43	135.88	21.25	20.88	43.13
B_0	0.608	127.50	20.00	22.00	40.00
B_1	0.704	125.25	23.38	21.63	43.25
B_2	0.895	141.88	25.13	24.25	38.60
B_3	1.29	154.75	24.38	21.38	44.63
F-S	45.14**	766.61**	64.06**	11.12**	10.90**
F-B	17.05**	111.01**	4.12*	1.17NS	6.11**
F-S.B	32.30**	608.65**	32.99**	8.99**	2.72*
CD - S	0.1268	3.931	2.380	2.638	3.490
CD - B.	0.1268	3.931	2.380	-	3.490
CD - S.B	0.2537	7.862	5.760	5.276	6.982

significantly superior to the other treatment combinations. The lowest value of 55.50 mg kg^{-1} was recorded by T_4 (S_0B_3) and all the treatments were significantly superior to it.

Coming to the main effects of different levels of S and B, S_2 (15.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the significantly superior values of 182.63 mg kg^{-1} and 154.13 mg kg^{-1} respectively. They were significantly superior to all the other levels. The lowest values were recorded by S_0 (0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) as 101.50 mg kg^{-1} and 123.50 mg kg^{-1} respectively.

As in the case of the first crop, perusal of the data pertaining to the second crop showed that the interaction of different levels of S and B was found to be significant. The values ranged from 52.50 mg kg^{-1} to 256.50 mg kg^{-1} recorded by T_4 (S_0B_3) and T_{11} (S_2B_2) respectively.

As regard to the main effect of different levels of S and B, the iron content of the grain was significantly influenced by the application of different these nutrients. S_2 (15.0 kg S ha^{-1}) was the significantly superior level for S (185.63 mg kg^{-1}) and was followed by S_3 (135.88 mg kg^{-1}). The lowest value recorded was that of S_0 (98.38 mg kg^{-1}). Among the levels of B, the significantly superior value was shown by B_3 (154.75 mg kg^{-1}) and the lowest value of 125.25 mg kg^{-1} was shown by B_1 (2.5 kg B ha^{-1}).

4.2.4.2.9 Manganese

It is explicit from the data that the Mn content of grain was significantly influenced by the application of different levels of S and B and their interaction with each other. S_2B_2 (T_{11}) recorded the maximum value of 51 mg kg^{-1} among the different treatment combinations which was significantly superior to the other treatments and was followed by T_{10} (S_2B_1) and T_8 (S_1B_3) which were on par. The lowest value of 11.50 mg kg^{-1} was recorded by T_1 (S_0B_0).

In the case of individual effect of different levels of S and B, the content of this nutrient showed an increasing trend with the increase in level of S upto S_2 (15.0 kg S ha^{-1}) and then exhibited a decreasing trend. The highest significant value recorded was 33.25 mg kg^{-1} by S_2 (15.0 kg S ha^{-1}). Among the levels of B, no definite trend was observed. However, the significantly highest value of 28 mg kg^{-1} was recorded by B_1 (2.5 kg B ha^{-1}) followed by B_2 (5.0 kg B ha^{-1}). The lowest values of 18.38 mg kg^{-1} and 18.75 mg kg^{-1} were shown by S_3 and B_3 respectively.

Statistical analysis of the data for the second crop showed that the Mn content of grain showed significant response with the application of S and B. The highest value of 52 mg kg^{-1} was shown by T_{11} (S_2B_2) which was the significantly the superior treatment followed by T_{10} (S_2B_1) and T_9 (S_2B_0) which were on par. The lowest value of 14 mg kg^{-1} was shown by T_1 (S_0B_0).

As for the individual effects of these nutrients, S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) were the superior levels for S and B which recorded the values of 33.88 mg kg^{-1} and 25.13 mg kg^{-1} respectively. The lowest value in both cases was shown by S_1 (19.25 mg kg^{-1}) and B_0 (20 mg kg^{-1})

4.2.4.2.10 Copper

The critical examination of the data pertaining to the Cu content of the first crop showed that the interaction of different levels of S and B had significant effect on the Cu of the grain and the highest value of 37.50 mg kg^{-1} was recorded by T_{11}(S_2B_2). All the other treatments were significantly lower to it. The lowest value of 16 mg kg^{-1} was recorded by T_1 (S_0B_0) and T_2 (S_0B_1) which received no S.

The effect of different levels of S and B were highly significant for the Cu content of grain in the first crop. The significantly superior value of 25.38 mg kg^{-1} was recorded by S_3 (30.0 kg S ha^{-1}) followed by S_2. Among the different levels of B, B_2 (5.0 kg B ha^{-1}) recorded the significantly highest value of 24.13 mg kg^{-1}. The lowest values of 18.25 mg kg^{-1} and 20 mg kg^{-1} were shown by S_0 and B_1 respectively.

On critical examination of the data it had been observed that the interaction between S and B was also significant for the B content of grain and the highest value of 37 mg kg^{-1} being recorded by T_{11} (S_2B_2) which was significantly superior to all other treatments. This was followed by T_8 (S_1B_3) and T_{10} (S_2B_1) which were on par with each other. The lowest value of 17 mg kg^{-1} was shown by T_7 (S_1B_2).

In the second crop also, application of different levels of S and B had significant effect on the Cu content of grain. S_2 (15.0 kg ha^{-1}) was the significantly superior S level (26.63 mg kg^{-1}) followed by S_1 (22.5 ppm). However, the highest value of 24.25 mg kg^{-1} was shown by B_2 (5.0 kg B ha^{-1}). The lowest values of 19.25 mg kg^{-1} and 21.38 mg kg^{-1} were shown by S_0 (0.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively.

4.2.4.2.11 Zinc

It is evident from the data that the effect of treatments were highly significant for the Zn content of grain of the first crop. The interaction effect of different levels of S and B were also significant. The values varied between 34.0 mg kg^{-1} and 49.50 mg kg^{-1} recorded by T_1 (S_0B_0) and T_{16} (S_3B_3) respectively. T_{16} (S_3B_3) was on par with T_9, T_{14} (S_3B_1) and T_8(S_1B_3).

The individual effects of these nutrients were also significant with regard to the parameter under consideration. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the superior treatments which recorded the values of 45.00 mg kg^{-1} and 44.25 mg kg^{-1} respectively. This was followed by S_2 (15.0 kg S ha^{-1}) and B_1. S_0 (0.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) recorded the lowest value of 36.75 mg kg^{-1} and 38.75 mg kg^{-1} respectively.

Perusal of the data regarding the second crop showed that application of different levels of S and B significantly influenced the Zn content of grain. The interaction between different levels of S and B were significant and the content ranged from 35.50 mg kg^{-1} to 50.50 mg kg^{-1} recorded by T_1 (S_0B_0) and T_{12}(S_2B_3) respectively. T_{12} (S_2B_3) was on par with T_8 (S_1B_3), T_{14} (S_3B_1) and T_9 (S_2B_0). The lowest level of S recorded the lowest values which were on par as shown by the treatments T_1 (S_0B_0), T_2 (S_0B_1), T_3 (S_0B_2) and T_4 (S_0B_3).

As for the individual effects of S and B, S_2 (15.0 kg S ha^{-1}) recorded the highest value of 45.38 mg kg^{-1} followed by S_3. The lowest value of 36.00 mg kg^{-1} was recorded by S_0. Among the levels of B, B_3 (7.5 kg B ha^{-1}) recorded the highest value of 44.63 mg kg^{-1}. B_2 (5.0 kg B ha^{-1}) showed the lowest value of 38.60 mg kg^{-1}.

4.2.5 Effect of treatments on the uptake of nutrients

4.2.5.1 Bhusa (Table 19 a and 19 b)

4.2.5.1.1 Nitrogen

The uptake of N was significantly influenced by the application of S and B. The interaction of different levels of S and B had significant influence on the parameter. T_{16} (34.79 kg ha^{-1}) was the superior treatment followed by T_{15} (S_3B_2) and T_{14} (S_3B_1). The lowest value of 6.89 kg ha^{-1} was shown by T_1 (S_0B_0) which was preceded by T_4 (S_0B_3) and T_2 (S_0B_1).

Statistical analysis of the data shows that the individual effects of S and B had significant effect on the uptake of N by bhusa of the first crop. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest value of 30.79 kg ha^{-1} and 24.47 kg ha^{-1} respectively. The lowest values of 8.22 kg ha^{-1} and 15.59 kg ha^{-1} was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

Perusal of the data shows the significant effect of the interaction of S and B on the N uptake by the second crop. The highest value was recorded for T_{16} (28.84 kg ha^{-1}) which was significantly superior to all other treatments. The lowest value of 9.27 kg $ha^{-1}$was produced by T_1 (S_0B_0) and was on par with T_2 (S_0B_1).

Regarding the individual effects of these nutrients, significant influence of their different levels was observed. Among the levels of S and B, S_3 (30 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 26.35 kg ha^{-1} and 17.67 kg ha^{-1} respectively. The lowest values of 9.67 kg ha^{-1} and 15.83 kg ha^{-1} was recorded by S_0 (0.0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.5.1.2 Phosphorus

Significant influence for the application of S and B was recorded for the uptake of P by bhusa. As in the case of the nutrient concentration, the highest value of 13.51 kg $ha^{-1}$was shown by T_{12} (S_2B_3) which was on par with T_{11} (S_2B_2). The lowest value of 7.09 kg $ha^{-1}$was shown by T_1 (S_0B_0) and all the treatments were significantly higher than it.

S_2 (15 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the significantly superior levels which recorded the values of 11.93 kg ha^{-1} and 11.12 kg ha^{-1} respectively. The lowest values of 9.06 kg ha^{-1} and 8.66 kg ha^{-1} were recorded by S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

In the second field experiment, the uptake of P was significantly influenced by the application of different levels of S and B. The interaction between different levels of S and B was also been observed to be significant and the highest value of 15.92 kg ha^{-1} was recorded by T_{12} (S_2B_3) followed by T_{11} (S_2B_1) which were on par with each other. The lowest value of 8.51 kg ha^{-1} was recorded by T_1(S_0B_0).

Considering individual effects of these nutrients, S_2 (15 kg S ha^{-1}) recorded the highest value of 15.50 kg $ha^{-1}$and was significantly superior to the other levels. The lowest value was recorded by S_0 (9.92 kg S ha^{-1}). Among the levels of B, B_3 (7.5 kg B ha^{-1}) was the superior level which recorded a value of 13.52 kg ha^{-1}. This was followed by the next higher level of B_2 (12.97 kg B ha^{-1}). The lowest value of 11.93 kg ha^{-1} was shown by B_0 (0.0 kg B ha^{-1}).

4.2.5.1.3 Potassium

The levels of S and its interaction with B were significant on the uptake of K by bhusa. Perusal of the data shown in Table shows that the interaction of S and B has a significant effect on the uptake of K and the highest value of 30.21 kg ha^{-1} was shown by T_{16} (S_3B_3) which was on par with T_{12}(S_2B_3). The lowest value of 16.71 kg ha^{-1} was shown by T_1 (S_0B_0).

S_2 (15 kg ha^{-1}) recorded the significantly highest value of 24.61 kg ha^{-1} followed by S_3. The lowest value of 20.01 kg ha^{-1} was produced by S_0 (0.0 kg S ha^{-1}).

Table 19a Nutrient uptake of bhusa at harvest of the first crop (kg ha^{-1})

Treatments	N	P	K	Ca	Mg	S
$S_0 B_0$	6.89	7.09	16.71	75.81	19.78	4.81
$S_0 B_1$	8.42	8.24	17.05	74.86	18.88	5.95
$S_0 B_2$	8.29	10.30	19.91	63.59	44.07	5.89
$S_0 B_3$	9.32	10.64	26.32	53.00	19.62	6.64
$S_1 B_0$	10.53	7.90	17.85	92.50	19.41	7.49
$S_1 B_1$	12.86	9.16	21.52	76.36	20.36	6.43
$S_1 B_2$	18.43	9.20	24.26	100.94	27.58	8.91
$S_1 B_3$	24.26	9.50	29.52	63.56	28.69	8.79
$S_2 B_0$	20.69	10.07	19.46	109.87	29.81	9.48
$S_2 B_1$	23.81	11.45	24.72	48.35	28.98	9.62
$S_2 B_2$	27.69	12.70	25.41	78.01	27.35	10.53
$S_2 B_3$	29.53	13.51	28.84	62.63	30.16	10.65
$S_3 B_0$	24.26	9.38	21.17	114.36	19.91	11.56
$S_3 B_1$	31.82	9.61	21.97	75.82	51.25	11.82
$S_3 B_2$	32.28	10.76	23.35	91.20	30.98	11.91
$S_3 B_3$	34.79	10.87	30.21	67.96	20.96	12.07
S_0	8.22	9.06	20.01	66.81	25.59	5.82
S_1	16.53	8.95	23.30	83.34	24.01	7.91
S_2	25.41	11.93	24.61	74.71	29.07	10.05
S_3	30.79	10.16	24.17	87.33	27.94	11.84
B_0	15.59	8.61	18.79	98.13	19.39	8.34
B_1	19.23	9.61	21.31	68.84	29.87	8.45
B_2	21.68	10.74	23.23	83.43	32.49	9.32
B_3	24.47	11.12	28.73	61.79	24.86	9.55
F-S	148.99**	105.47**	7.92**	12.3899 **	3.8949 *	16.39**
F-B	22.68**	24.73**	2.89^{NS}	38.5019 **	25.0157 **	4.20*
F-S.B	14.18**	10.51**	5.36**	5.72**	22.9365**	2.86*
CD - S	3.520	1.180	2.980	10.841	4.820	5.163
CD - B.	3.520	1.180	2.980	10.841	4.820	5.163
CD - S.B	7.040	2.360	5.960	21.680	9.640	10.326

Table 19b. Nutrient uptake by bhusa at harvest of the second crop (kg ha^{-1})

Treatments	N	P	K	Ca	Mg	S
$S_0 B_0$	9.27	8.51	16.15	45.21	17.89	4.82
$S_0 B_1$	9.57	9.92	17.30	74.97	20.19	4.96
$S_0 B_2$	9.66	10.50	20.19	76.12	26.53	6.53
$S_0 B_3$	10.15	10.73	20.76	66.89	19.50	6.62
$S_1 B_0$	11.60	11.81	18.23	77.39	14.10	7.20
$S_1 B_1$	11.99	12.18	26.99	76.12	19.26	7.38
$S_1 B_2$	12.11	12.99	28.38	79.58	28.49	7.98
$S_1 B_3$	12.92	13.80	27.91	75.35	28.49	8.97
$S_2 B_0$	18.20	15.23	20.88	99.19	15.57	9.69
$S_2 B_1$	18.27	15.73	25.61	51.90	16.49	10.13
$S_2 B_2$	18.53	15.11	27.68	72.66	30.10	10.38
$S_2 B_3$	18.80	15.92	28.84	53.06	30.45	10.89
$S_3 B_0$	24.22	12.11	21.34	77.28	18.15	11.77
$S_3 B_1$	25.03	12.46	26.53	72.66	27.25	12.57
$S_3 B_2$	27.27	13.27	31.61	85.35	30.10	12.67
$S_3 B_3$	28.84	13.66	34.14	65.74	24.80	12.97
S_0	9.67	9.92	18.59	65.80	21.02	5.74
S_1	12.16	12.69	25.38	77.11	22.81	7.89
S_2	18.43	15.50	25.75	69.20	23.15	10.27
S_3	26.35	12.87	28.42	75.25	29.21	12.50
B_0	15.83	11.93	19.15	74.76	19.03	8.37
B_1	16.22	12.57	24.11	68.91	26.18	8.77
B_2	16.89	12.97	26.97	78.43	25.17	9.39
B_3	17.67	13.52	27.92	65.26	25.81	9.87
F-S	20.90**	28.78**	3.87*	8.08**	13.56**	20.73**
F-B	6.88**	3.47*	0.246^{NS}	10.12**	12.11**	16.44**
F-S.B	6.57**	21.29**	0.638^{NS}	15.31**	26.97**	20.80**
CD - S	6.075	4.022	7.282	5.573	2.917	4.958
CD - B.	6.075	4.022	-	5.573	2.917	4.958
CD - S.B	12.151	8.044	-	11.146	5.834	9.916

Though the levels of B were not significant on the uptake of K, the highest value of 28.73 kg ha^{-1} was shown by B_3 (7.5 kg B ha^{-1}) and the lowest value of 18.79 kg ha^{-1} was shown by B_0 (0 kg B ha^{-1}).

Perusal of the data pertaining to the second crop showed that T_{16} (S_3B_3) showed the highest value of 34.14 kg ha^{-1} and was followed by T_{15} (S_3B_2). The lowest value of 16.15 kg ha^{-1} was recorded by T_1 (S_0B_0).

As regard to the individual effects, the uptake of K was significantly influenced by the levels of S only. S_3 (30 kg S ha^{-1}) was the superior level and recorded a value of 28.42 kg ha^{-1} which was on par with S_2. The lowest value of 18.59 kg ha^{-1} was shown by S_0. B_3 (7.5 kg B ha^{-1}) recorded the highest value among the levels of B and an uptake of 27.92 kg ha^{-1} was recorded. The lowest value of 19.15 kg ha^{-1} was noticed in B_0 (0.0 kg B ha^{-1}).

4.2.5.1.4 Calcium

As in the case of the nutrient concentration in bhusa, Ca uptake showed a similar trend such that with increase in levels of B, the uptake showed a decreasing trend and vice versa for the levels of S. T_{13} (S_3B_0) showed the highest value of 114.36 kg ha^{-1} followed by T_9 (S_2B_0) and T_7 (S_1B_2) and they were on par and the lowest value of 48.35 kg ha^{-1} was shown by T_{10} (S_2B_1) which was preceded by T_4 (S_0B_3).

As for the individual effects, application of S and B has a significant effect on the uptake of Ca by bhusa. S_3 (30.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) recorded the significantly superior values of 87.33 kg ha^{-1} and 98.13 kg ha^{-1} respectively. The lowest values of 66.81 kg ha^{-1} and 61.79 kg ha^{-1} was recorded by S_0 (0.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively.

In the case of the second crop, the interaction of S and B had significant effect on the Ca uptake. The values ranged between 45.21 kg ha^{-1} and 99.19 kg ha^{-1} recorded by T_1 (S_0B_0) and T_9 (S_2B_0) respectively which was significantly superior to all the other treatments.

Considering the main effects of different levels of S and B, the uptake of Ca was significantly influenced by the application of different levels of S and B. The highest value of 77.11 kg ha^{-1} was shown by S_1 (7.5 kg S ha^{-1}) followed by S_3 (75.25 kg S ha^{-1}) and were on par with each other. The lowest values of 65.80 kg ha^{-1} was shown by S_0 (0 kg ha^{-1}). Among the levels of B, the highest value of 78.43 kg ha^{-1} was recorded by B_2. The lowest value of 65.26 kg ha^{-1} was recorded by B_3.

4.2.5.1.5 Magnesium

The interaction effect of S and B was significant in the case of uptake of Mg by bhusa. The highest value of 51.25 kg ha^{-1} was shown by T_{14} (S_3B_1) which was significantly superior to the other treatments and the lowest value of 19.41 kg ha^{-1} was shown by T_4 (S_0B_3).

The levels of S and B registered significant effect on the uptake of Mg by bhusa. The highest value of 29.07 kg ha^{-1} was recorded by S_2 (15.0 kg S ha^{-1}) and was on par with S_3. The lowest value of 24.01 kg ha^{-1} was recorded S_1 (7.5 kg S ha^{-1}) which was on par with S_0. Among the different levels of B the significantly highest value of 32.49 kg ha^{-1} was recorded by B_2 (5.0 kg B ha^{-1}) and the lowest value of 19.39 kg ha^{-1} was recorded by B_0 (0.0 kg B ha^{-1}).

In the case of second crop also, the interaction between different levels of S and B had significant effect on the uptake. T_{12} (S_2B_3) was the significantly superior treatment (30.45 kg ha^{-1}). The lowest value of 14.10 kg ha^{-1} was shown by T_5 (S_1B_0).

Regarding the main effects of these nutrients, significant effect of their different levels on the parameter was observed. With the increase in the level of S, an increasing trend was noticed and the highest value of 29.21 kg ha^{-1} was recorded by S_3. S_0 (0 kg S ha^{-1}) recorded the lowest value of 21.02 kg ha^{-1}. Among the different levels of B, B_1 (2.5 kg B ha^{-1}) recorded the highest value of 26.18 kg ha^{-1} which was on par with B_2 (5.0 kg B ha^{-1}) and B_3 (7.5 kg B ha^{-1}). The lowest value recorded was 19.03 kg ha^{-1} shown by B_0.

4.2.5.1.6 Sulphur

Perusal of the data showed that the interaction of S and B was significant for the uptake of S by the bhusa. The highest value of 12.07 kg ha^{-1} was shown by T_{16} (S_3B_3) followed by T_{15} (S_3B_2) and they were on par. With increasing levels of S and B, the uptake also showed an increasing trend. The lowest value of 4.81 kg ha^{-1} was shown by T_1 (S_0B_0) which received no S.

The uptake of S was significantly influenced by the application of different levels of S and B. S_3 (30.0 kg S ha^{-1}) recorded the highest value of 11.84 kg ha^{-1} and was followed by S_2 (15.0 kg S ha^{-1}) and they were on par with each other. B_3 (7.5 kg B ha^{-1}) recorded the highest value of 9.55 kg ha^{-1} which was on par with B_2 (5 kg B ha^{-1}). The lowest values of 5.82 and 8.34 kg ha^{-1} was shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

Analysis of the data pertaining tot the second crop revealed that the positive influence of the increasing levels of S and B was reflected in their interaction. The highest value of 12.97 kg ha^{-1} was recorded by T_{16} (S_3B_3) followed by T_{15} (S_3B_2) and T_{14} (S_3B_1) and the lowest value of 4.82 kg $ha^{-1}$was recorded by T_1 (S_0B_0).

The different levels of S and B individually also had significant influence on the uptake of S by the second crop. Statistical analysis of the levels of the nutrients showed that S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the superior levels of these nutrients. S_3 (30.0 kg S ha^{-1}) recorded the value of 12.50 kg ha^{-1} followed by S_2 (10.27 kg S ha^{-1}). Among the levels of B, B_3 (7.5 kg B ha^{-1}) recorded the significantly highest value of 9.87 kg ha^{-1}. The lowest value of 5.74 kg ha^{-1} and 8.37 kg ha^{-1} was recorded by S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

4.2.5.1.7 Boron (Table 20 a and 20 b)

In the first crop, application of treatments had significant effect on the uptake of B. The interaction of S and B levels was also significant for the uptake of B. The values ranged from 39.5 μg $plant^{-}$to 183.77 μg $plant^{-1}$ recorded by T_1

(S_0B_0) and T_{16} (S_3B_3) which was significantly superior to the other treatments respectively.

Among the levels of S, the highest value of 125.93 µg plant^{-1} was recorded by S_3 (30 kg S ha^{-1}) and was the significantly superior level. The lowest values of 68.77µg plant^{-1} and 65.06 µg plant^{-1} were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively. Perusal of the data revealed that, with increasing levels of B in the treatments, the uptake also increased. The maximum uptake of 144.48 µg plant^{-1} was recorded with B_3 (7.5 kg B ha^{-1}) among the levels of B followed by B_2 (5.0 kg B ha^{-1}) which were on par with each other. The lowest value of 65.06 µg plant^{-1} was shown by B_0 (0 kg B ha^{-1})

In the second crop also, the positive influence of increasing levels of B and S on the corresponding uptake was noticed. The interaction of S and B also registered significant effect on the B uptake and the highest value of 156.62 µg plant^{-1}was recorded by T_{16} (S_3B_3). The lowest value of 21.89 µg plant^{-1} was recorded by T_1 (S_0B_0).

Among the individual effects, the highest values of 114.14 µg plant^{-1}and 121.62 µg plant^{-1} for the B uptake was recorded by S_3 (30 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}). S_0 (0.0 kg S ha^{-1}) recorded the lowest value of 53.22 µg plant^{-1}. Among the different levels of B, the lowest value was recorded by B_0 (42.48 µg plant^{-1}).

4.2.5.1.8 Iron

The uptake of micronutrients were significantly influenced by the application of S and B as evident from the data pertaining to the first crop. The interaction of different levels of S and B were also significant for the uptake of Fe by bhusa. T_7 (S_1B_2) was the significantly superior treatment which recorded a value of 1993.90 µg plant^{-1}. The lowest value was recorded by T_1 (S_0B_0) (721 µg plant^{-1}).

The uptake showed an increasing trend with increasing levels of S and B. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) registered the highest values of 1451.29

Table 20 a. Micronutrient uptake of bhusa at harvest of the first crop (μg plant^{-1})

Treatments	B	Fe	Mn	Cu	Zn
$S_0 B_0$	39.50	721.35	405.10	54.96	158.00
$S_0 B_1$	52.83	1030.50	377.00	72.14	147.50
$S_0 B_2$	81.41	1573.23	282.00	82.44	117.00
$S_0 B_3$	101.33	1559.49	343.50	82.44	117.00
$S_1 B_0$	84.64	783.18	229.50	109.92	124.00
$S_1 B_1$	79.76	968.67	364.00	75.57	144.20
$S_1 B_2$	135.41	1933.91	185.55	68.70	140.70
$S_1 B_3$	149.63	1191.95	288.50	133.97	110.10
$S_2 B_0$	77.49	755.70	432.00	82.44	247.40
$S_2 B_1$	91.16	1140.42	240.40	109.92	106.45
$S_2 B_2$	110.47	1446.14	508.50	89.31	175.00
$S_2 B_3$	143.24	1157.60	443.00	75.57	237.20
$S_3 B_0$	92.95	978.98	471.00	92.75	158.00
$S_3 B_1$	115.07	961.80	484.50	103.05	82.00
$S_3 B_2$	146.19	1157.60	309.40	76.944	117.00
$S_3 B_3$	183.77	1470.18	319.00	82.44	247.30
S_0	68.77	1221.14	352.00	73.03	135.00
S_1	112.39	1391.18	267.00	97.07	130.00
S_2	105.59	1124.96	406.00	89.31	151.00
S_3	125.93	1451.29	396.00	88.82	192.00
B_0	65.06	809.97	384.00	85.05	120.00
B_1	84.71	1195.38	366.00	90.20	172.00
B_2	118.37	1527.75	321.00	79.35	137.00
B_3	144.48	1653.95	349.00	93.64	178.00
F-S	27.32**	66.60**	41.44**	101.60**	19.60**
F-B	9.01**	225.31**	7.46**	120.45**	19.11**
F-S.B	29.02**	81.03**	24.21**	99.28**	14.46**
CD - S	11.11	74.53	29.67	12.26	19.05
CD - B.	11.11	74.53	29.67	12.26	19.05
CD - S.B	22.35	149.07	59.34	24.52	38.11

Table 20 b. Micronutrient uptake by bhusa at harvest of the second crop (μg plant⁻¹)

Treatments	B	Fe	Mn	Cu	Zn
$S_0 B_0$	21.89	716.00	422.30	41.52	93.50
$S_0 B_1$	34.16	1013.78	370.20	65.74	155.50
$S_0 B_2$	66.46	1286.90	297.75	64.01	141.50
$S_0 B_3$	90.23	1304.70	360.00	66.43	114.00
$S_1 B_0$	36.04	754.10	245.50	98.61	114.00
$S_1 B_1$	61.26	1418.50	394.50	83.04	162.50
$S_1 B_2$	102.15	2031.00	186.50	80.62	141.50
$S_1 B_3$	144.21	1130.00	301.00	100.34	111.00
$S_2 B_0$	47.33	747.50	460.40	76.12	259.00
$S_2 B_1$	86.97	1055.75	242.00	96.88	111.00
$S_2 B_2$	93.14	1320.00	529.00	93.42	166.00
$S_2 B_3$	137.49	1096.50	439.40	73.35	238.50
$S_3 B_0$	64.59	975.50	501.70	86.50	159.00
$S_3 B_1$	97.51	945.00	501.50	100.34	169.60
$S_3 B_2$	137.77	1166.00	307.90	85.81	124.50
$S_3 B_3$	156.62	2062.00	328.70	86.50	260.00
S_0	53.22	1080.00	363.00	59.44	126.00
S_1	85.93	1340.00	282.00	90.65	132.00
S_2	91.27	1060.00	418.00	84.98	194.00
S_3	114.14	1280.00	410.00	89.82	178.00
B_0	42.48	798.00	407.00	75.70	156.00
B_1	69.99	1110.00	377.00	86.50	150.00
B_2	110.40	1460.00	330.00	80.96	143.00
B_3	121.62	1390.00	357.00	81.66	181.00
F-S	12.31**	195.80**	27.95**	339.88**	43.92**
F-B	12.83**	1060.37**	7.60**	445.52**	37.31**
F-S.B	7.86**	430.46**	19.54**	343.59**	45.01**
CD - S	17.10	26.339	35.567	23.720	12.025
CD - B.	17.10	26.339	35.567	23.720	12.025
CD - S.B	34.30	52.679	71.134	47.440	24.050

μg plant^{-1} and 1653 μg plant^{-1} respectively and were significantly higher than their next higher levels. The lowest values of 1221.24 μg plant^{-1} and 809.97 μg plant^{-1} was shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

In the second crop, significant effect was noticed for the interaction of different levels of S and B. T_{16} (S_3B_3) recorded the highest value of 2062 μg plant^{-1}and was on par with T_7 (2030 μg plant^{-1}). The lowest value of 716 μg plant^{-1}was noticed in T_1 (S_0B_0) which was on par with T_9 (S_2B_0), both of which received no B.

The uptake of iron was significantly influenced by the application of treatments S_1 (7.5 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) were the superior levels of S and B and showed the values 1340 μg plant^{-1} and 1460 μg plant^{-1}respectively. The lowest value was recorded by S_2 (15.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) as 1060 μg plant^{-1} and 798 μg plant^{-1}.

4.2.5.1.9 Manganese

It is explicit from the data that the interaction of different levels of S and B were significant for the uptake of Mn and the highest value of 508.50 μg plant^{-1} was recorded by T_{11} (S_2B_2) and was on par with T_{14} (S_3B_1) and T_{11} (S_2B_2). The lowest value of 185.55 μg plant^{-1} was recorded by T_7 (S_1B_2) preceded by T_5 (S_1B_0) and T_{10} (S_2B_1).

As regard to the individual effects of S and B, the uptake of Mn was also significantly influenced by the application of different levels of these nutrients. The highest value of 406 μg plant^{-1} was recorded by S_2 (15.0 kg S ha^{-1}) and was on par with S_3. B_0 (0.0 kg B ha^{-1}) recorded the highest value of 384 μg plant^{-1} and was on par with B_1. The lowest values of 267 μg plant^{-1} and 321 μg plant^{-1} were shown by S_1 (7.5 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively.

In the second crop, the interaction between S and B were significant and the values varied from 186.5 μg plant^{-1} and 529 μg plant^{-1}being recorded by T_7(S_1B_2) and T_{11}(S_2B_2) respectively.

Considering the individual effects of S and B uptake of Mn was also significantly influenced by the levels of S and B. Among the levels S_2 (15.0 kg S ha^{-1}) recorded the highest value of 418 µg $plant^{-1}$and B_0 (0.0 kg B ha^{-1}) recorded the highest value for B 407 µg $plant^{-1}$. The lowest value was recorded by S_1(282 µg $plant^{-1}$) and B_2(330 µg $plant^{-1}$).

4.2.5.1.10 Copper

In the first crop, the interaction of S and B was highly significant for the uptake of uptake of copper was highly significant with the application of S and B. The superior value of 133.97 µg $plant^{-1}$was recorded with T_{16} (S_3B_3). The lowest value of 54.96 µg $plant^{-1}$ was recorded by T_1.

Perusal of the data presented in table shows that application of different levels of S and B had significant effect on the uptake of Cu by bhusa. Among the levels of S and B, S_1 (7.5 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 97.07 µg $plant^{-1}$ and 93.64 µg $plant^{-1}$respectively and were significantly superior to other levels. The lowest values were recorded by S_0 (73.03 µg $plant^{-1}$) and B_2 (79.35 µg $plant^{-1}$) respectively.

In the second crop, the interaction between different levels of S and B was also significant with range of values between 41.52 µg $plant^{-1}$ and 100.34 µg $plant^{-1}$ being recorded by T_1(S_0B_0) and T_8(S_1B_3) respectively.

Individually significant influence of the different levels of S and B was also observed and S_1 (7.5 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) recorded the highest value of 90.65 µg $plant^{-1}$and 86.50 µg $plant^{-1}$ respectively. The lowest values of 59.44 µg $plant^{-1}$and 75.70 µg $plant^{-1}$ in both cases were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) respectively.

4.2.5.1.11 Zinc

The interaction of different levels of S and B significantly influenced the uptake of Zn and the highest value of 247 µg $plant^{-1}$was recorded by T_9 (S_2B_0) which just followed by T_{16} (S_3B_3) and were on par with each other. The lowest value of 82 μg plant^{-1} was recorded by T_{14} (S_3B_1). All the treatments were significantly higher than it.

As in the case of other micronutrients, the uptake of Zn was also significantly influenced by the application of different levels of S and B. S_3 (30.0 kg S ha^{-1}) recorded the significantly highest value of 192 μg plant^{-1} followed by S_2 (151 μg plant^{-1}). Among the levels of B, the highest value of 178 was recorded by B_3 (7.5 kg B ha^{-1}) followed by B_0 (172 μg plant^{-1}) and were on par with each other. S_1 (7.5 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) recorded the lowest values of 130 μg plant^{-1} and 120 μg plant^{-1} respectively.

In the case of second crop, T_{16} (S_3B_3) recorded the highest value of 260.0 μg plant^{-1}followed by T_9 (S_2B_0) and T_{12} (S_2B_3). The lowest value of 93.5 μg plant^{-1}was recorded by T_1 (S_0B_0).

The different levels of S and B had significant effect on the Zn uptake and the highest value of 194 μg plant^{-1} was recorded by S_2 (15.0 kg S ha^{-1}) followed by S_3. The highest value among the different levels of B_3 was recorded by 181 μg plant^{-1}. The lowest values of 126 μg plant^{-1} and 143 μg plant^{-1} were shown by S_0 (0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively.

4.2.5.2 Grain (Table 21 a and 21 b)

4.2.5.2.1 Nitrogen

Data of the first crop regarding the uptake of nutrients by grain shows that uptake of N was significantly influenced by the application of treatments. The interaction effect of S and B also registered significant influence on the uptake of N. It followed the same trend as the case of grain yield and T_{16} (S_3B_3) was the superior treatment and the lowest being shown by T_1 (S_0B_0). The recorded values were between 11.43 kg ha^{-1} and 40.91 kg ha^{-1} respectively.

As for the individual effects of S and B, uptake of N was significantly influenced by their increasing levels. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the significantly superior levels than the other levels and recorded the values of 32.46 kg ha^{-1} and 28.14 kg ha^{-1} respectively. The lowest values of 18.99 kg

Table 21 a. Nutrient uptake of grain at harvest of the first crop (kg ha^{-1})

Treatments	N	P	K	Ca	Mg	S
$S_0 B_0$	11.43	0.914	2.05	5.20	1.22	1.01
$S_0 B_1$	22.63	1.93	5.35	18.11	3.08	1.95
$S_0 B_2$	22.20	2.99	5.29	13.53	1.96	2.17
$S_0 B_3$	20.02	4.16	5.03	8.40	2.14	1.97
$S_1 B_0$	15.50	1.50	3.49	9.84	1.86	2.25
$S_1 B_1$	22.75	2.25	4.95	13.35	1.92	3.98
$S_1 B_2$	22.38	3.99	4.89	15.60	2.25	4.11
$S_1 B_3$	27.17	4.77	5.51	14.62	3.22	5.26
$S_2 B_0$	20.01	2.48	4.53	12.77	1.85	3.80
$S_2 B_1$	22.32	3.48	4.80	15.27	2.20	3.91
$S_2 B_2$	26.71	4.98	5.85	18.82	2.59	4.73
$S_2 B_3$	25.93	4.66	5.56	9.37	2.72	4.94
$S_3 B_0$	2.73	3.16	4.10	12.10	1.09	3.73
$S_3 B_1$	38.03	5.80	7.17	19.71	2.84	6.10
$S_3 B_2$	24.97	3.72	4.74	14.59	1.58	4.56
$S_3 B_3$	40.91	7.07	7.96	14.90	3.40	7.78
S_0	18.99	2.43	4.31	10.88	1.85	1.76
S_1	21.78	3.03	4.70	13.31	2.30	3.82
S_2	23.71	3.86	5.17	13.90	1.99	4.34
S_3	32.46	4.84	5.93	15.70	2.13	5.50
B_0	17.92	1.92	3.49	9.76	1.55	2.56
B_1	26.16	3.29	5.55	16.66	2.52	3.95
B_2	24.19	3.93	5.20	15.58	2.08	3.94
B_3	28.14	5.13	6.00	11.75	2.24	4.81
F-S	13.13**	4.68*	0.729^{NS}	3.43*	0.142^{NS}	5.25**
F-B	15.50**	11.61**	4.54*	3.86*	1.73^{NS}	4.17*
F-S.B	15.68**	8.16*	1.08^{NS}	2.96*	1.67^{NS}	5.28**
CD - S	3.189	0.838	-	4.970	-	1.570
CD - B.	3.189	0.838	1.440	4.970	-	1.570
CD - S.B	6.380	1.677	-	9.940	-	3.140

Table 21 b. Nutrient uptake by grain at harvest of the second crop (kg ha^{-1})

Treatments	N	P	K	Ca	Mg	S
$S_0 B_0$	10.85	1.49	1.70	4.49	1.06	1.27
$S_0 B_1$	24.15	3.32	5.23	18.52	3.17	2.68
$S_0 B_2$	23.53	3.29	5.01	16.19	2.37	2.67
$S_0 B_3$	22.44	3.21	6.07	9.29	1.22	2.65
$S_1 B_0$	17.28	2.21	3.67	9.65	2.16	2.61
$S_1 B_1$	24.78	3.23	5.29	12.44	2.09	4.18
$S_1 B_2$	22.14	3.00	4.81	14.81	1.98	3.92
$S_1 B_3$	27.10	3.69	5.64	8.55	2.88	4.55
$S_2 B_0$	26.47	3.88	5.23	14.95	2.76	4.67
$S_2 B_1$	28.27	3.83	5.29	16.17	2.30	4.99
$S_2 B_2$	27.97	4.47	5.76	12.09	2.95	4.93
$S_2 B_3$	26.68	4.24	5.38	9.52	1.50	4.38
$S_3 B_0$	26.07	4.06	4.95	11.53	1.29	4.32
$S_3 B_1$	33.05	5.38	6.19	15.87	1.90	5.77
$S_3 B_2$	24.76	4.21	4.77	14.60	1.83	4.51
$S_3 B_3$	40.66	6.66	7.81	23.72	3.735	7.98
S_0	20.11	2.79	4.32	11.36	1.95	2.31
S_1	22.78	3.02	4.84	12.12	2.27	3.79
S_2	27.39	4.11	6.45	13.19	2.37	4.74
S_3	31.05	5.07	6.01	16.43	2.19	5.58
B_0	19.76	2.81	4.06	10.15	1.81	3.05
B_1	27.48	3.92	5.47	15.75	2.36	4.40
B_2	24.70	3.77	6.07	14.42	2.28	4.06
B_3	28.85	4.38	6.24	12.77	2.33	4.75
F-S	10.13**	19.22**	25.18**	20.81**	1.45NS	53.35**
F-B	7.16**	7.85**	22.54**	24.27**	2.98NS	19.05**
F-S.B	3.63*	13.44**	9.36**	21.48**	9.22**	11.71**
CD - S	5.147	0.6139	0.5977	1.475	0.4490	0.5075
CD - B.	5.147	0.6139	0.5977	1.475	0.4490	0.5075
CD - S.B	10.295	1.227	1.1956	2.950	0.8980	1.015

ha^{-1} and 17.92 kg ha^{-1} were shown by S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

Analysis of the data shows that different levels of S applied had a significant effect on the N uptake by grain of the second crop. Significant effect of the interaction between different levels of S and B was also observed. T_{16} (S_3B_3) was significantly superior to other treatments and recorded a value of 40.66 kg ha^{-1} followed by T_{14} (S_3B_1).The lowest value of 10.85 kg ha^{-1} was recorded by T_1 (S_0B_0).

Considering the main effects of S and B, S_3 (30.0 kg S ha^{-1}) recorded the highest value of 31.05 kg ha^{-1} and was on par with S_2. The lowest value of 20.11 kg ha^{-1} was shown by S_0. Among the levels of B, B_3 (7.5 kg B ha^{-1}) recorded a value of 28.85 which was the highest and was on par with B_2 (5 kg B ha^{-1}). The lowest value of 19.76 kg ha^{-1} was recorded by B_0 (0.0 kg B ha^{-1}).

4.2.5.2.2 Phosphorus

Perusal of the data indicated that the grain uptake of P was significantly influenced by the application of treatments. The interaction of different levels of S and B also significantly influenced the uptake of P and recorded the values of 7.07 kg ha^{-1} and 0.914 kg ha^{-1} produced by T_{16} (S_3B_3) and T_1 (S_0B_0) respectively.

The different levels of S and B had significant effect on this parameter. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 4.84 kg ha^{-1} and 5.13 kg ha^{-1} which were significantly superior to the other levels of these nutrients. The lowest values of 2.43 kg ha^{-1} and 1.92 kg ha^{-1} were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

A critical examination of the data pertaining to the second crop showed significant effect of the interaction between different levels of S and B. T_{16} (S_3B_3) recorded the significantly highest value of 6.66 kg ha^{-1}. The lowest value of 1.49 was recorded by T_1 (S_0B_0).

As regard to the individual effects of S and B, statistical analysis of the data shows the significant in influence of S and B levels on the P uptake by grain.

The highest value of 5.07 kg ha^{-1} was shown by S_3 (30.0 kg S ha^{-1}) followed by S_2 (15.0 kg B ha^{-1}) and were on par. Among the different levels of B applied, B_3 (7.5 kg B ha^{-1}) recorded the significantly highest value of 4.38 kg ha^{-1}. The lowest value of 2.79 kg ha^{-1} and 2.81 kg ha^{-1} were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

4.2.5.2.3 Potassium

Statistical analysis of the data revealed that the interaction effect of S and B could not register any significant effect on the uptake of K by grain of the first crop. However the values ranged from 2.05 kg ha^{-1} to 7.96 kg ha^{-1} being recorded by T_1 (S_0B_0) and T_{16} (S_3B_3) respectively.

Regarding the individual effects, the uptake of K was significantly influenced by the different levels of B only. The highest value of 5.93 kg ha^{-1} among the different levels of S was recorded by S_3. The lowest values of 4.31 kg ha^{-1} and 3.49 kg ha^{-1} in both cases were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively. B_3 (7.5 kg B ha^{-1}) recorded the significantly highest value of 6.00 kg ha^{-1} which was on par with B_2 and B_1 (2.5 kg B ha^{-1}).

In the case of the second crop also the interaction effect was also found to be significant and the highest value of 7.81 kg ha^{-1} was shown by T_{16} (S_3B_3) and was significantly superior to the other treatment combinations. The lowest value of 1.70 kg ha^{-1} was shown by T_1. All the treatments recorded significantly higher values compared to that of T_1 (S_0B_0).

Perusal of the data presented in table shows that the uptake of K was significantly influenced by the application of different levels of S and B. S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) recorded the highest value of 6.45 and 6.24 kg ha^{-1} among the different levels of S and B. The lowest value of 4.32 kg ha^{-1} and 4.06 kg ha^{-1} was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.5.2.4 Calcium

The uptake of Ca was significantly influenced by the application of treatments in the first crop. The highest and lowest values for the uptake of Ca followed the trend same as that of the other nutrients being recorded by T_{14} (S_3B_1) and T_1 (S_0B_0) respectively for Ca also and the values ranged from kg ha^{-1} 5.20 to 19.71 kg ha^{-1}.

The different levels of S showed an increasing trend for the uptake and the superior value of 15.70 kg ha^{-1} was noticed with S_3 (30.0 kg S ha^{-1}) followed by S_2. Among the levels of B, the highest value of 16.66 kg ha^{-1} was shown by B_1 (2.5 kg B ha^{-1}).The lowest values of 10.88 kg ha^{-1} and 9.76 kg ha^{-1} was shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

Data regarding the second crop shows that the uptake of Ca was significantly influenced by the application of treatment. The interaction between different levels of S and B were found to be significant and the recorded values were between 23.72 kg ha^{-1}(T_{16}) and 4.49 kg ha^{-1}(T_1).

Perusal of the data shows an increasing trend with increase in the level of S applied and the highest value of 16.43 kg ha^{-1} was shown by S_3 (30.0 kg S ha^{-1}) followed by S_2. The lowest value of 11.36 kg ha^{-1} was recorded by S_0. Among the different levels of B, B_1 (2.5 kg B ha^{-1}) recorded the highest value of 15.75 kg ha^{-1} followed by B_2. B_0 (0.0 kg B ha^{-1}) recorded the lowest value of 10.15 kg ha^{-1}.

4.2.5.2.5 Magnesium

A critical examination of the data on first crop showed that the interaction of different levels of S and B or their individual effects could not produce any significant effect on the uptake of Mg by grain. However the values ranged between 1.22 kg ha^{-1} and 3.40 kg ha^{-1} produced by T_1 (S_0B_0) and T_{16} (S_3B_3) respectively.

With regard to the individual effects, it has been observed that the superior value of 2.30 kg ha^{-1} and 2.52 kg ha^{-1} among the different levels of S and B was recorded by S_1 (7.5 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively. The lowest values of 1.85 kg ha^{-1} and 1.55 kg ha^{-1} were shown by S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

In the case of the second crop, the interaction between different levels of S and B was found to have high significance and the highest value of 3.74 kg ha^{-1} was recorded by T_{16} (S_3B_3). The lowest value of 1.06 kg ha^{-1} was recorded by T_1 (S_0B_0) which was on par with T_4 (S_0B_3).

However as for the individual effects of different levels of S and B, no significance was observed between the different levels of S and B applied on the grain uptake of Mg. S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) recorded the highest values of 2.37 kg ha^{-1} and 2.36 kg ha^{-1} respectively. The lowest values of 1.95 kg ha^{-1} and 1.81 kg ha^{-1} were recorded by S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.5.2.6 Sulphur

The interaction between the levels of S and B was significant for the uptake of S as evident from the data. The significantly highest value of 7.78 kg ha^{-1} was recorded by T_{16} (S_3B_3). The lowest value of 1.01 kg ha^{-1} was recorded by T_1 (S_0B_0) preceded by T_2 (S_0B_1) and were on par.

With regard to the individual effects, the levels of S and B had a significant effect, with the significantly highest values being recorded by S_3 (30.0 kg ha^{-1}) and B_3 (7.5 kg B ha^{-1}) and the values were 5.50 kg ha^{-1} and 4.81 kg ha^{-1}respectively. The lowest values of 1.76 kg ha^{-1} and 2.56 kg ha^{-1} was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

It had been statistically observed that the interaction between different levels of S and B were also much significant in the second crop also. The values varied from 1.27 kg ha^{-1} to 7.98 kg ha^{-1} being shown by recorded by T_1 (S_0B_0) and T_{16} (S_3B_3) respectively.

Perusal of the data presented for the second crop showed that the uptake of S was significantly influenced by the application of different levels of S and B. It showed an increasing trend with increase in the level of these nutrients. The highest value of 5.58 kg $ha^{-1}$was recorded by S_3 (30.0 kg S ha^{-1}) which was significantly superior to the other levels. The lowest value of 2.31 kg ha^{-1} was shown by S_0. Among the levels of B, the highest value of 4.75 kg ha^{-1} was recorded by B_3 (7.5 kg B ha^{-1}) and the lowest value of 3.05 kg $ha^{-1}$was shown by B_0 (0.0 kg B ha^{-1}).

*4.2.5.2.7 **Boron*** (Table 22 a and 22 b)

The uptake of B was significantly influenced by the application of treatments. On critical examination of the data pertaining to the first crop, it had been observed that the interaction between different levels of S and B significantly influenced the parameter. The highest value of 5.59 µg $plant^{-1}$ was shown by T_{16} (S_3B_3) and was followed by T_7 (S_1B_2). The lowest value of 0.514 µg $plant^{-1}$ was recorded by T_1.

As regard to the individual effects of different levels of S and B, the treatment effects were found to be significant. The highest values of 3.84 µg $plant^{-1}$ and 2.83 µg $plant^{-1}$ were recorded by S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively. The lowest values recorded were 1.94 µg $plant^{-1}$ and 1.97 µg $plant^{-1}$ as shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

In the second crop, the grain uptake of B was significantly influenced by the application of treatments. The interaction between different levels of S and B was found to be much significant. The highest value of 5.48 µg $plant^{-1}$was recorded by T_{16} (S_3B_3). The lowest value of 0.70 µg $plant^{-1}$ was recorded by T_1 (S_0B_0) which received no S and B.

Considering individual effects, among the different levels of S and B, the highest value was recorded by S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) which were 4.07 µg $plant^{-1}$ and 3.15 µg $plant^{-1}$ respectively. The lowest values of 1.84 µg $plant^{-1}$ and 1.89 µg $plant^{-1}$ were shown by S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.5.2.8 Iron

In the first crop the grain uptake of Fe was significantly influenced by the application of S and B. The interaction of different levels of S and B was significant for the uptake of iron by grain and the highest value of 858 µg $plant^{-1}$

Table 22 a. Micronutrient uptake of grain at harvest of the first crop (µg plant^{-1})

Treatments	B	Fe	Mn	Cu	Zn
$S_0 B_0$	0.514	167.85	42.20	35.85	59.60
$S_0 B_1$	1.080	439.85	111.45	66.15	144.50
$S_0 B_2$	1.240	471.10	57.10	66.60	123.85
$S_0 B_3$	1.840	156.75	75.30	56.35	110.40
$S_1 B_0$	0.798	144.10	32.14	46.00	78.23
$S_1 B_1$	1.210	355.00	34.90	56.04	130.55
$S_1 B_2$	5.160	248.00	49.20	46.65	98.40
$S_1 B_3$	1.050	832.00	101.15	88.55	151.20
$S_2 B_0$	3.070	500.65	88.65	65.70	134.70
$S_2 B_1$	1.250	477.50	97.00	70.55	127.70
$S_2 B_2$	1.680	858.00	172.35	126.00	135.15
$S_2 B_3$	2.860	429.00	55.55	52.50	152.70
$S_3 B_0$	3.500	488.94	51.45	62.95	123.05
$S_3 B_1$	3.590	357.70	92.75	71.15	155.60
$S_3 B_2$	2.690	229.87	34.75	46.90	108.50
$S_3 B_3$	5.590	736.50	63.55	81.05	186.25
S_0	1.940	309.00	72.00	56.00	110.00
S_1	2.050	309.00	54.00	59.00	115.00
S_2	2.210	566.00	103.00	79.00	138.00
S_3	3.840	453.00	61.00	66.00	143.00
B_0	1.970	325.00	54.00	53.00	99.00
B_1	2.560	408.00	84.00	66.00	140.00
B_2	2.690	452.00	78.00	72.00	116.00
B_3	2.830	539.00	74.00	70.00	150.00
F-S	5.96**	86.19**	65.05**	22.68**	16.09**
F-B	4.85*	58.34**	23.99**	16.67**	30.75**
F-S.B	4.89**	107.77**	48.48**	30.18**	7.55**
CD - S	1.150	35.07	8.147	6.292	12.52
CD - B.	1.150	35.07	8.147	6.292	12.52
CD - S.B	2.300	70.14	16.295	12.584	25.04

Table 22 b. Micronutrient uptake by grain at harvest of the second crop (μg plant^{-1})

Treatments	B	Fe	Mn	Cu	Zn
$S_0 B_0$	0.700	143.00	33.00	33.50	59.65
$S_0 B_1$	3.650	365.50	89.90	61.50	124.59
$S_0 B_2$	1.670	456.00	53.90	68.30	113.80
$S_0 B_3$	1.920	161.00	78.05	64.30	113.27
$S_1 B_0$	0.803	149.50	37.80	48.30	81.25
$S_1 B_1$	1.020	362.50	45.28	63.75	72.70
$S_1 B_2$	5.070	233.50	46.25	47.75	99.85
$S_1 B_3$	1.720	826.50	100.75	86.25	162.75
$S_2 B_0$	3.270	563.00	101.60	79.45	145.05
$S_2 B_1$	2.290	869.00	107.70	82.05	140.95
$S_2 B_2$	2.230	530.50	176.05	124.5	139.00
$S_2 B_3$	3.030	440.50	54.30	57.45	156.80
$S_3 B_0$	3.350	499.00	54.12	68.35	119.00
$S_3 B_1$	4.670	379.00	83.00	75.15	163.40
$S_3 B_2$	3.210	225.00	40.30	47.05	108.75
$S_3 B_3$	5.480	719.50	59.35	83.00	173.20
S_0	1.840	283.00	56.00	57.00	103.00
S_1	2.250	391.00	65.00	62.00	104.00
S_2	2.710	601.00	110.00	86.00	145.00
S_3	4.070	456.00	59.00	68.00	141.00
B_0	1.890	339.00	57.00	57.00	101.00
B_1	2.910	537.00	81.00	71.00	125.00
B_2	2.930	409.00	79.00	72.00	115.00
B_3	3.150	446.00	73.00	73.00	152.00
F-S	51.42**	186.12**	78.35**	28.26**	7.59**
F-B	17.49**	71.86**	15.54**	9.09**	6.43**
F-S.B	30.57**	146.38**	39.18**	20.27**	2.14**
CD - S	40.83	29.32	8.559	7.202	25.204
CD - B.	40.83	29.32	8.559	7.202	25.204
CD - S.B	81.66	58.65	17.218	14.405	50.409

was recorded by T_{11} (S_2B_2) followed by T_8 (S_1B_3) and were on par with each other. The lowest value of 144 µg $plant^{-1}$ was recorded by T_5 (S_1B_0) preceded by T_4 (S_0B_3).

Regarding the individual effects of S and B, S_2 (15.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the levels which recorded the superior values of 566 µg $plant^{-1}$ and 539 µg $plant^{-1}$ respectively. The other levels were significantly lower than it. The lowest value for both the cases was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) recorded as 309 µg $plant^{-1}$ and 325 µg $plant^{-1}$ respectively.

In the case of the second crop, the uptake of Fe was significantly influenced by the application of S and B. The interaction between different levels of S and B was also found to be highly significant. The highest value of 868 µg $plant^{-1}$ was recorded by T_{10}(S_2B_1) followed by T_8(S_1B_3) and T_{16}(S_3B_3) which were on par and the lowest value of 143 µg $plant^{-1}$ by T_1(S_0B_0).

Among the different levels of S and B, S_2 (15.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest value of 601 µg $plant^{-1}$ and 446 µg $plant^{-1}$ respectively. The lowest value in both case was recorded by S_0 (283 µg $plant^{-1}$) and B_0 (339 µg $plant^{-1}$).

4.2.5.2.9 Manganese

In the first crop perusal of the data found that the interaction effect of different levels of S and B were significant and the highest value of 172.45 µg $plant^{-1}$ was recorded by T_{11} (S_2B_2) which was the significantly the superior level. The lowest value of 32.00 µg $plant^{-1}$ was recorded by T_5 (S_1B_0) and was on par with T_1(S_0B_0).

As for the individual effects of S and B, S_2 (15.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) recorded the superior values of 103.00 µg $plant^{-1}$ and 84 µg $plant^{-1}$ respectively. The lowest value of 54.00 µg $plant^{-1}$ was shown by S_1 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

In the second crop, the interaction between different levels of S and B was also found to be significant and the values ranged between 33.00 μg $plant^{-1}$ and 176.05 μg $plant^{-1}$ recorded by T_1 (S_0B_0) and T_{11} (S_2B_2) respectively.

Significant influence of the different levels of S and B has been recorded. S_2 (15.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) were the significantly superior level for S and B and recorded the values of 110 μg $plant^{-1}$ and 81 μg $plant^{-1}$ respectively. The lowest value of 56 μg $plant^{-1}$ and 57 μg $plant^{-1}$ was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

4.2.5.2.10 Copper

The uptake of copper was highly significantly influenced by the levels of S and B and their interaction with each other. T_{11} (S_2B_2) recorded the significantly highest value of 126 μg $plant^{-1}$ followed by T_8 (S_1B_3) and T_{16} (S_3B_3) both of which were on par and they both received B at the highest level of 7.5 kg ha^{-1}. The lowest value of 35.85 μg $plant^{-1}$ was recorded by T_1. All the treatments recorded values significantly higher than it.

When the individual effects were considered S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) were the significantly superior levels of S and B and recorded the values of 79 μg $plant^{-1}$ and 72 μg $plant^{-1}$ respectively. The lowest values of 56 μg $plant^{-1}$ and 53 μg $plant^{-1}$ were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

Perusal of the data showed significant effect of the interaction between different levels of S and B and followed the trend as that of the first crop. The highest value of 124.5 μg $plant^{-1}$ was recorded by T_{11} (S_2B_2) followed by T_8 (S_1B_3) and T_{16}(S_3B_3). The lowest value of 33.5 μg $plant^{-1}$ was recorded by T_1 (S_0B_0).

Regarding the individual effects of different levels of S and B, significant influence of the different levels of S and B was reported. S_2 (15.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest value of 86 μg $plant^{-1}$ and 73 μg $plant^{-1}$ respectively. The lowest value recorded was 57 μg $plant^{-1}$ in both the cases being shown by S_0 (0 kg S ha^{-1}) and B_0 (0 kg B ha^{-1})

4.2.5.2.11 Zinc

Perusal of the data showed that the interaction effect of S and B was significant for the Zn uptake. T_{16} (S_3B_3) recorded the highest value of 186.25 µg $plant^{-1}$ and was significantly superior to other treatments. This was followed by T_{14} (S_3B_1) which also received S at the highest level. T_1 (S_0B_0) which received no S and B recorded the lowest value of 59.60 µg $plant^{-1}$

Application of different levels of S and B and their interaction significantly influenced the uptake of Zn by grain. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values among the different levels of S and B as 143 µg $plant^{-1}$ and 150 µg $plant^{-1}$ respectively. The lowest values of 110 µg $plant^{-1}$ and 99 µg $plant^{-1}$ were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

In the second crop, the interaction between different levels of S and B was found to be non significant. T_{16} (S_3B_3) recorded the highest value of 173.20 µg $plant^{-1}$ followed by T_{14} (S_3B_1) (163.40 µg $plant^{-1}$). T_1 (S_0B_0) recorded the lowest value (59.65 µg $plant^{-1}$).

Considering the individual effects of different levels of S and B, significant influence of the different levels of these nutrients was reflected. Among the different levels of these nutrients, S_2 (15.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the superior values of 145 µg $plant^{-1}$ and 152 µg $plant^{-1}$ respectively. The lowest value of 103 µg $plant^{-1}$ and 101 µg $plant^{-1}$ was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.6 Total Uptake of nutrients (Table 23 a and 23 b)

4.2.6.1 Nitrogen

It had been observed that the interaction of different levels of S and B had significant effect on the total N uptake by the first crop. The highest value of 75.70 kg ha^{-1} was shown by T_{16} (S_3B_3) and was significantly superior to the other treatment combinations. The lowest value of 18.32 kg ha^{-1} was recorded by T_1 (S_0B_0). All the treatments were significantly higher than it.

Table 23 a. Total nutrient uptake (Grain + Bhusa) at harvest of the first crop (kg ha^{-1})

Treatments	N	P	K	Ca	Mg	S
$S_0 B_0$	18.32	8.00	18.76	81.01	21.0	5.82
$S_0 B_1$	31.05	10.17	22.40	92.97	21.96	7.90
$S_0 B_2$	30.49	13.29	25.20	77.12	46.03	8.06
$S_0 B_3$	29.34	14.80	31.35	61.4	20.86	8.61
$S_1 B_0$	26.03	9.40	21.34	102.34	21.27	9.74
$S_1 B_1$	35.61	11.41	26.47	89.71	22.28	10.41
$S_1 B_2$	40.81	13.19	29.15	116.54	29.83	13.02
$S_1 B_3$	51.43	14.27	35.03	78.18	31.91	14.05
$S_2 B_0$	40.71	12.55	23.99	122.64	31.66	13.28
$S_2 B_1$	46.13	14.93	29.52	63.62	31.18	13.53
$S_2 B_2$	54.40	17.68	31.26	96.83	29.94	15.26
$S_2 B_3$	55.46	18.17	34.40	72.00	31.51	15.59
$S_3 B_0$	36.99	12.54	25.27	126.46	9.66	15.29
$S_3 B_1$	69.85	15.41	29.14	95.53	54.09	17.92
$S_3 B_2$	57.25	14.48	28.09	105.79	32.56	16.47
$S_3 B_3$	75.70	17.94	38.17	82.86	24.36	19.85
S_0	27.21	11.49	24.32	77.69	27.44	7.58
S_1	38.31	11.98	28.00	96.65	26.31	11.73
S_2	49.12	15.79	29.78	88.61	31.06	14.39
S_3	63.25	15.00	30.10	103.03	30.07	17.34
B_0	33.51	10.53	22.28	107.89	20.94	10.90
B_1	45.39	12.90	26.86	85.50	32.39	12.40
B_2	45.87	14.67	28.43	99.01	34.57	13.26
B_3	52.61	16.25	34.73	73.54	27.10	14.36
F-S	100.04**	115.74**	5.65**	0.812^{NS}	0.153^{NS}	8.51**
F-B	15.32**	31.45 **	3.33*	1.19^{NS}	0.552^{NS}	28.88**
F-S.B	15.56**	17.83 **	4.58**	1.00^{NS}	0.729^{NS}	16.11**
CD - S	5.294	1.178	3.384	29.72	4.35	5.901
CD - B.	5.294	1.178	3.384	29.72	4.35	5.901
CD - S.B	10.589	2.356	6.768	59.44	8.70	11.802

Table 23 b. Total nutrient uptake (Grain + Bhusa) at harvest of the second crop (kg ha^{-1})

Treatments	N	P	K	Ca	Mg	S
$S_0 B_0$	20.12	10.00	17.85	49.70	18.95	6.09
$S_0 B_1$	33.72	13.24	22.53	93.49	23.36	7.64
$S_0 B_2$	33.19	13.79	25.20	92.31	28.90	9.20
$S_0 B_3$	32.59	13.94	26.83	76.18	20.72	9.27
$S_1 B_0$	28.88	14.02	21.90	87.04	16.26	9.81
$S_1 B_1$	36.77	15.41	32.28	88.56	21.35	11.56
$S_1 B_2$	34.25	15.99	33.19	94.39	30.47	11.90
$S_1 B_3$	40.02	17.49	33.55	83.90	31.37	13.52
$S_2 B_0$	44.67	15.99	26.11	114.14	18.33	14.36
$S_2 B_1$	46.54	16.29	30.90	68.07	18.79	15.12
$S_2 B_2$	46.50	17.74	33.44	84.75	33.05	15.31
$S_2 B_3$	45.48	22.58	34.22	62.58	31.95	15.27
$S_3 B_0$	50.29	19.29	26.29	88.81	14.44	16.09
$S_3 B_1$	58.08	21.11	32.72	88.53	29.15	18.34
$S_3 B_2$	52.03	19.32	36.38	99.95	31.93	17.18
$S_3 B_3$	69.50	17.90	41.95	89.46	28.535	20.95
S_0	29.78	12.71	22.91	77.16	22.97	8.05
S_1	34.94	15.71	30.22	89.23	25.08	11.68
S_2	45.82	20.57	32.20	82.39	25.52	15.01
S_3	57.40	16.98	34.43	91.68	31.4	18.08
B_0	35.59	14.74	23.21	84.91	20.84	11.42
B_1	43.70	16.49	29.58	84.66	28.54	13.17
B_2	41.59	16.74	33.04	92.85	27.45	13.45
B_3	46.52	17.90	34.16	78.03	28.14	14.62
F-S	17.47 **	2.55^{NS}	4.64 *	12.35 **	14.52**	25.63 **
F-B	9.82 **	2.69^{NS}	4.12*	11.99 **	14.67 **	25.52**
F-S.B	4.41 **	3.07 *	3.854**	23.26**	27.94**	21.39**
CD - S	9.254	-	7.150	5.28	2.853	4.924
CD - B.	9.254	-	7.150	5.28	2.853	4.924
CD - S.B	7.748	7.748	14.300	10.55	5.707	9.848

Coming to individual effects, significant effect of the different levels of S and B on the uptake of N had been observed. Among the different levels of S, the highest value of 63.25 kg $ha^{-1}$was recorded by S_3 (30.0 kg S ha^{-1}) which was significantly superior to the other levels. The lowest value of 27.21 kg $ha^{-1}$was recorded by S_0. The other levels were significantly superior to it. Significant effect of the different levels of B was also recorded and the highest value of 52.61 kg ha^{-1} was recorded by B_3 (7.5 kg B ha^{-1}). The lowest value of 33.51 kg ha^{-1} was recorded by B_0 (0.0 kg B ha^{-1}). This was significantly lower to the other levels.

Perusal of the data indicated that the interaction between different levels of S and B had much significance on the total N uptake by the second crop. The highest value of 69.50 kg ha^{-1} was recorded by T_{16} (S_3B_3). T_1 (S_0B_0) recorded the lowest value of 20.12 kg ha^{-1}.

The main effect of different levels of S and B were also found to be significant. The highest value of 57.40 kg ha^{-1} was recorded by S_3 (30 kg S ha^{-1}). S_0 (0 kg S ha^{-1}) was the significantly lowest among all the levels and showed a value of 29.78 kg ha^{-1}. Among the B levels, B_3 (7.5 kg B ha^{-1}). recorded the highest value of 46.52 kg ha^{-1} and the lowest value of 35.59 kg ha^{-1} was shown by B_0 (0 kg B ha^{-1}).

4.2.6.2 Phosphorus

Perusal of the data pertaining to the first crop showed that the interaction between different levels of S and B had significant influence on the total uptake of P. The highest value of 18.17 kg ha^{-1} was recorded by T_{12} (S_2B_3) followed by T_{16} (S_3B_3) and were on par with each other. T_1 (S_0B_0) recorded the significantly lowest value of 8.00 kg ha^{-1}.

The levels of S and B individually had also significant effect on the total P uptake. Among the different levels of S, S_2 (15.0 kg S ha^{-1}) recorded the highest value of 15.79 kg ha^{-1} which was significantly superior to the other levels. The lowest value of 11.49 kg ha^{-1} was shown by S_0 (0 kg S ha^{-1}). B_3 (7.5 kg B ha^{-1})

recorded the highest value of 16.29 kg ha^{-1} and was the significantly superior level. The lowest value of 10.53 kg ha^{-1} was shown by B_0 (0.0 kg B ha^{-1}).

Perusal of the data pertaining to the second crop showed significant effect of the interaction between different levels of S and B. The highest value of 22.58 kg ha^{-1} was recorded by T_{16} (S_3B_3). The lowest value of 10.00 kg ha^{-1} was recorded by T_1 (S_0B_0).

Among the main effect of levels of S and B, S_2 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 20.57 kg ha^{-1} and 17.90 kg ha^{-1} respectively. The lowest values recorded were 12.71 kg ha^{-1} and 14.74 kg ha^{-1} recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.6.3 Potassium

Statistical analysis of data of the first crop revealed that the interaction of different levels of S and B and also the individual effect of different levels of S were significant on the total uptake of K.

T_8 (S_1B_3) recorded the highest value of 38.17 kg ha^{-1}. The lowest value of 18.76 kg ha^{-1} was recorded by T_1 (S_0B_0).

Among the different levels of S, S_3 (30 kg S ha^{-1}) recorded the highest value of 30.10 kg ha^{-1} and the lowest value of 24.32 kg ha^{-1} was shown by S_0. The highest value of 34.73 kg ha^{-1} among the different levels of B was recorded by B_3 (7.5 kg B ha^{-1}) followed by B_2 (5.0 kg ha^{-1}). The lowest value of 22.28 kg ha^{-1} was recorded by B_0 (0.0 kg B ha^{-1}).

Perusal of the data concerning the second crop showed that the interaction between different levels of S and B registered significant effect on the K uptake. The highest value of 41.95 kg ha^{-1} was shown by T_{16} (S_3B_3). The lowest value of 17.85 kg ha^{-1} was recorded by T_1 (S_0B_0).

Regarding the individual effect of S and B which were significant on the parameter, S_3 (30 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest value of 34.43 kg ha^{-1} and 34.16 kg ha^{-1} respectively. The lowest values of 22.91 kg ha^{-1}

and 23.21 kg ha^{-1} was produced by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.6.4 Calcium

In the first crop the total uptake of Ca was not significantly influenced by the application of different levels of S and B or their interaction. In the case of interaction between different levels of S and B, the highest value of 126.46 kg ha^{-1} was recorded by T_{13} (S_3B_0) followed by T_9 (S_2B_0). The lowest value of 61.40 kg ha^{-1} was recorded by T_4 (S_0B_3).

When the individual effects were considered, the highest value of 103.03 kg ha^{-1} and 107.89 kg ha^{-1} among the different levels of S and B was recorded by S_3 (30.0 kg ha^{-1}) and B_0 (0.0 kg ha^{-1}) respectively. The lowest value of 77.69 kg ha^{-1} and 73.54 kg ha^{-1} was recorded by S_0 (0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively.

Perusal of the data with regard to the second crop showed significant influence of the interaction between different levels of S and B and their individual effects on the parameter studied. The highest value of 114.14 kg ha^{-1} was recorded by T_9 (S_2B_0) which was significantly superior to the other treatment combinations. The lowest value of 49.70 kg ha^{-1} was shown by T_1. All the other treatments recorded significantly higher values compared to T_1 (S_0B_0).

Considering the individual effects of S and B, S_3 (30.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) recorded the significantly highest values of 91.68 kg ha^{-1} and 92.85 kg ha^{-1} respectively. The lowest values of 77.16 kg ha^{-1} and 78.03 kg ha^{-1} were recorded by S_0 (0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively.

4.2.6.5 Magnesium

Perusal of the data pertaining to the first crop revealed that the interaction between different levels of S and B and their individual effects were not significant with regard to the total uptake of Mg. However the values range from 9.66 kg ha^{-1} to 54.09 kg ha^{-1} recorded by T_{13} (S_3B_0) and T_{14} (S_3B_1) respectively.

In the case of the individual effects of different levels of S and B, the highest value of 31.06 kg ha^{-1} and 34.57 kg ha^{-1} was recorded by S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively. The lowest values recorded by the two nutrient were 26.31 kg ha^{-1} and 20.94 kg ha^{-1} recorded by S_1 (7.5 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

Statistical analysis of the data pertaining to the total Mg uptake by the second crop showed the significant effect of the interaction between different levels of S and B. The significantly highest value of 33.05 kg ha^{-1} was observed with T_{11} (S_2B_2). The lowest value recorded was 14.44 kg ha^{-1} which was produced by T_{13} (S_3B_0).

As for the individual effects of S and B which were also significant, the highest values of 31.40 kg ha^{-1} and 28.54 kg ha^{-1} was recorded by S_3 (30.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively. The lowest values of 22.97 kg ha^{-1} and 20.84 kg ha^{-1} were produced by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively. These were significantly lower compared to the other levels.

4.2.6.6 Sulphur

Perusal of the data on the total S uptake by the first crop revealed significant influence of the interaction between different levels of S and B in combination and individually. The highest value of 19.85 kg ha^{-1} was recorded by T_{16} (S_3B_3) followed by T_{14} (S_3B_1) and were on par with each other. The lowest value of 5.82 kg ha^{-1} was recorded by T_1 (S_0B_0).

The effect of different levels of S and B individually were also significant. S_3 (30.0 kg S ha^{-1}) recorded the highest value of 17.34 kg ha^{-1} followed by S_2. The lowest value of 7.58 kg ha^{-1} was recorded by S_0. Among the different levels of B, B_3 (7.5 kg B ha^{-1}) recorded the highest value of 14.36 kg ha^{-1} followed by B_2 (13.46 kg B ha^{-1}) and they were on par. The lowest value of 10.90 kg ha^{-1} was recorded by B_0 (0.0 kg B ha^{-1}).

On critical examination of the data of the second crop showed that the treatment effects were significant on the total uptake of S. T_{16} (S_3B_3) recorded the highest value of 20.95 kg ha^{-1} which was on par with T_{14} (S_3B_1). The lowest value of 6.09 kg ha^{-1} was produced by T_1 (S_0B_0) and was on par with T_3 (S_0B_2) and T_2 (S_0B_1).

Regarding the individual effect of different levels of S and B, which were significant, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}), recorded the highest values of 18.08 kg ha^{-1} and 14.62 kg ha^{-1} respectively. The lowest values of 8.05 kg ha^{-1} and 11.42 kg ha^{-1} were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.6.7 ***Boron*** (24 a and 24 b)

Statistical analysis of the data of the first crop shows the significant effect of the interaction between different levels of S and B and also their individual effects on the total uptake of B. It has been found that the significantly highest value of 189.36 µg $plant^{-1}$ was recorded by T_{16} (S_3B_3). The lowest value of 40.01 µg $plant^{-1}$ was shown by T_1 ($S0B_0$).

Among the different levels of S and B, it had been observed that the highest values of 129.77 µg $plant^{-1}$ and 147.31 µg $plant^{-1}$ were recorded by S_3 (30 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively. The lowest values of 70.71 µg $plant^{-1}$ and 67.03 µg $plant^{-1}$ were recorded by S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

On critical scrutiny of the data regarding the total uptake of B by the second crop indicated that the parameter was significantly influenced by the interaction of different levels of S and B. The values ranged between 36.50 µg $plant^{-1}$ and 149.02 µg $plant^{-1}$ as shown by T_1 (S_0B_0) and T_7 (S_1B_2) respectively.

Among the different levels of S and B, S_1 (7.5 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 99.25 µg $plant^{-1}$ and 104.93 µg $plant^{-1}$ respectively. The lowest values recorded were 50.84 µg $plant^{-1}$ and 45.89 µg $plant^{-1}$ by S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

Table 24 a. Total micronutrient uptake (Grain + Bhusa) at harvest of the first crop
(μg $plant^{-1}$)

Treatments	B	Fe	Mn	Cu	Zn
$S_0 B_0$	40.014	889.20	447.30	90.81	217.60
$S_0 B_1$	53.91	1470.35	488.45	138.29	292.00
$S_0 B_2$	82.65	2044.33	339.10	149.04	240.85
$S_0 B_3$	103.17	1716.24	418.80	138.79	227.40
$S_1 B_0$	85.438	927.28	261.64	155.92	202.23
$S_1 B_1$	80.97	1323.67	398.90	131.61	274.75
$S_1 B_2$	140.57	2181.91	234.75	115.35	239.10
$S_1 B_3$	150.68	2023.95	389.65	222.52	261.30
$S_2 B_0$	80.56	1256.35	520.65	148.14	382.10
$S_2 B_1$	92.41	1617.92	337.40	180.47	119.22
$S_2 B_2$	112.15	2304.14	680.85	215.31	310.15
$S_2 B_3$	146.10	1586.60	498.55	128.07	389.90
$S_3 B_0$	62.10	1467.92	522.45	155.7	281.05
$S_3 B_1$	118.66	1319.50	577.25	174.2	237.60
$S_3 B_2$	148.88	1387.47	344.15	123.844	225.50
$S_3 B_3$	189.36	2206.68	635.50	163.49	433.55
S_0	70.71	1530.14	424.00	129.03	245.00
S_1	114.44	1700.18	321.00	156.07	245.00
S_2	107.8	1690.96	509.00	168.31	289.00
S_3	129.77	1904.29	457.00	154.82	335.00
B_0	67.03	1134.97	438.00	138.05	219.00
B_1	87.27	1603.38	450.00	156.20	312.00
B_2	121.06	1979.75	399.00	151.35	253.00
B_3	147.31	2192.95	423.00	163.64	328.00
F-S	45.49**	32.81**	65.34**	112.56**	13.69**
F-B	19.63**	216.73**	4.98*	125.69**	10.99**
F-S.B	41.79**	67.64**	35.86**	104.31**	5.99**
CD - S	11.782	90.5746	29.55	41.97	44.03
CD - B.	11.782	90.5746	29.55	41.97	44.03
CD - S.B	23.564	181.1492	59.108	83.94	88.06

Table 24 b. Total micronutrient uptake (Grain +Bhusa) at harvest of the second crop

($\mu g\ plant^{-1}$)

Treatments	B	Fe	Mn	Cu	Zn
$S_0 B_0$	22.59	1094.08	460.15	75.02	460.15
$S_0 B_1$	37.81	1379.28	212.60	127.24	212.60
$S_0 B_2$	68.13	1742.90	351.65	132.31	351.65
$S_0 B_3$	92.15	1465.70	438.05	130.73	438.05
$S_1 B_0$	36.843	897.10	278.50	146.91	278.50
$S_1 B_1$	62.28	1781.00	439.785	146.79	439.79
$S_1 B_2$	107.22	2295.50	232.75	128.37	232.75
$S_1 B_3$	145.93	1956.50	401.75	186.59	401.75
$S_2 B_0$	50.60	1310.50	562.00	155.57	562.00
$S_2 B_1$	89.26	1586.25	349.70	178.93	349.70
$S_2 B_2$	95.37	2189.00	563.05	217.92	563.050
$S_2 B_3$	140.52	1537.00	493.70	130.8	493.70
$S_3 B_0$	67.94	1474.50	855.98	154.85	855.98
$S_3 B_1$	102.18	1095.00	584.50	175.49	584.50
$S_3 B_2$	140.98	1391.00	348.20	132.86	348.20
$S_3 B_3$	162.10	2750.50	388.05	169.5	388.05
S_0	55.06	1420.49	365.61	116.44	253.01
S_1	88.18	1732.53	338.20	152.65	252.59
S_2	93.98	1655.69	492.11	170.98	339.08
S_3	118.21	1677.75	544.18	157.82	300.21
B_0	44.37	1194.05	539.16	132.70	276.63
B_1	72.90	1460.38	396.65	157.50	277.28
B_2	113.55	1904.60	373.91	152.96	258.73
B_3	124.55	1927.43	430.39	154.66	332.26
F-S	29.065**	215.82 **	3.89 *	349.92 **	78.60 **
F-B	19.47**	1446.34 **	2.13NS	428.36 **	45.85 **
F-S.B	38.91**	563.66 **	2.15NS	329.09 **	47.56 **
CD - S	11.24	28.29	151.004	24.14	14.18
CD - B.	11.24	28.29	-	24.14	14.18
CD - S.B	22.47	56.58	-	48.29	28.37

4.2.6.8 Iron

Perusal of the data pertaining to the first crop showed that the interaction between different levels of S and B had significant effect on the uptake of Fe. The values ranged between 880.20 µg plant^{-1} and 2206.68 µg plant^{-1} recorded by $T_1(S_0B_0)$ and $T_{16}(S_3B_3)$ respectively.

It has been observed that the effect of different levels of S and B individually was also significant with regard to the uptake of Fe. Among the different levels of S, S_3 (30.00 kg S ha^{-1}) recorded the highest value of 1904.29 and the lowest value of 1530.14 µg plant^{-1} was recorded by S_0. In the case of different levels of B, B_3 (7.5 kg B ha^{-1}) recorded the highest value of 2192.95 µg plant^{-1} and the lowest value of 1134.97 µg plant^{-1} was recorded by B_0 (0.0 kg B ha^{-1}).

Statistical analysis of the data pertaining to the second crop showed that the iron uptake was significantly influenced by the interaction and main effect of different levels of S and B. The highest value of 2750.50 µg plant^{-1} was shown by $T_{16}(S_3B_3)$ and was significantly superior to all other treatments. The lowest value of 897.10 µg plant^{-1} was shown by T_5 (S_1B_0).

Regarding the individual effects of S and B, S_1 (7.5 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 1732.53 µg plant^{-1} and 1927.43 µg plant^{-1} respectively. The lowest values of 1420.49 µg plant^{-1} and 1194.05 µg plant^{-1} was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.6.9 Manganese

Significant effect of the interaction between different levels of S and B had been observed and it has been found that the highest value of 680.85 µg plant^{-1} was recorded by T_{11} (S_2B_2) which was significantly superior to all other treatments. The lowest value of 234.75 µg plant^{-1} was recorded by T_7 (S_1B_2) All the treatment recorded values significantly higher than it.

It could be statistically verified that the different levels of S and B individually also registered significant effect on the total uptake of Mn. S_2 (15.0

kg S ha^{-1}) recorded the significantly highest value of 509 µg $plant^{-1}$ and the lowest value of 321.00 was recorded by S_1. Among the different levels of B, B_1 (2.5 kg B ha^{-1}) recorded the highest value of 450.00 µg $plant^{-1}$ and the lowest value of 399.00 µg $plant^{-1}$was recorded by B_2 (5.0 kg B ha^{-1}).

Data analysis of the second crop showed that the different levels of S alone registered significant effect on the total uptake of Mn. The interaction between different levels of S and B could not produce any significant effect on the parameter. However the highest value of 855.98 µg $plant^{-1}$ was shown by T_{13} (S_3B_0) followed by T_{14} (S_3B_1). The lowest value recorded was that of 212.60 µg $plant^{-1}$by T_2 (S_0B_1).

Among the levels of S, S_3 (30.0 kg S ha^{-1}) produced the highest value of 544.18 followed by S_2. The lowest value of 338.20 µg $plant^{-1}$ was recorded by S_1.The different levels of B did not have any significant effect. The values varied between 373.91 µg $plant^{-1}$ and 539.16 µg $plant^{-1}$ recorded by B_2 (5.0 kg B ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.6.10 Copper

Perusal of the data on the total uptake of copper by the first crop showed that the interaction between different levels of S and B and also their individual levels had significant effect on the total uptake of Cu. Among the interaction effects, the highest value of 1386.05 µg $plant^{-1}$ was recorded by T_{16} (S_3B_3) and was significantly superior to all the other treatments. The lowest value of 283.15 µg $plant^{-1}$ was recorded by T_1 (S_0B_0).

With regard to the individual effects, the highest values of 686.00 µg $plant^{-1}$ and 815.00 µg $plant^{-1}$ were recorded by S_2 (15.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively. The lowest values were 519 µg $plant^{-1}$ and 460 µg $plant^{-1}$ were recorded by B_2 (5.0 kg B ha^{-1}) and S_0 (7.5 kg S ha^{-1}) respectively.

Perusal of the data presented in table showed that the Cu uptake was significantly influenced by the interaction between different levels of S and B. the highest and significant value of 1456.10 µg $plant^{-1}$ was recorded by T_{16} (S_3B_3).

The lowest value of 325.30 μg plant^{-1} was shown by T_5 (S_1B_0) and was on par with T_8 (S_1B_3).

Among the different levels of S and B which were significant individually S_2 (15.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) showed the highest values of 722.36 μg plant^{-1} and 855.33 μg plant^{-1}. The lowest values recorded were 409.31 μg plant^{-1} and 476.65 shown by S_1 (7.5 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively.

4.2.6.11 Zinc

Statistical analysis of the data pertaining to the first crop showed that the interaction between different levels of S and B had significant effect on the total uptake of Cu. The highest value of 433.55 μg plant^{-1} was recorded by T16 (S_3B_3) which was on par with T_{16} (S_3B_3). The lowest value of 119.22 μg plant^{-1} was recorded by T_{10} (S_2B_1) and was on par with T_5 (S_1B_0).

Among the levels of S and B, the highest values of 335 μg plant^{-1} and 328 μg plant^{-1} were recorded by S_3 (30 kg S ha^{-1}) and B_3. The lowest values of 245 μg plant^{-1} and 219 μg plant^{-1} were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

Perusal of the data pertaining to the total uptake of Zn by the second crop showed that the parameter was significantly influenced by the interaction between different levels of S and B and the levels of S and B individually. The highest value of 855.98 μg plant^{-1} was recorded by T_{13} (S_3B0) and was significantly superior to the other treatment combinations. The lowest value of 212.60 μg plant^{-1} was recorded by T_2 (S_0B_1).

Among the different levels of S and B, S_2 (15.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 339.08 μg plant^{-1} and 332.26 μg plant^{-1} respectively. The lowest values recorded were that shown by S_1 (7.5 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) as 252.59 μg plant^{-1} and 258.73 μg plant^{-1} respectively.

4.2.7 Nutrient Use Efficiency (Table 25 and 26)

4.2.7.1 Sulphur Use Efficiency

The yield improvement over unit quantity of S addition was calculated as S use efficiency. Critical examination of the data showed that the different levels of S tried had influence on S use efficiency and Apparent S Recovery.

In the first field experiment, an increasing trend was observed for S use Efficiency and the highest value of 8.33 was observed in S_3 (30.0 kg ha^{-1}) and the lowest value of 3.91 was shown by S_1 (7.5 kg S ha^{-1}).

In the second field experiment, the highest value of 9.26 was observed in S_3 (30.0 kg S ha^{-1}) and the lowest value of 2.33 as in the case of the first field experiment was shown by S_1 (7.5 kg S ha^{-1}).

4.2.7.2 Apparent S Recovery

Perusal of the data indicated that in the first field experiment, highest value of 45.33 was shown by S_1 (7.5 kg S ha^{-1}) and the lowest value of 27.30 was recorded by S_3 (30 kg S ha^{-1}).

It is obvious from the data pertaining to the second field experiment that the highest value of 48.40 was recorded by S_1 (7.50 kg S ha^{-1}) and the lowest value of 33.43 was shown by S_3 (30 kg S ha^{-1}).

4.2.7.3 Boron Use efficiency

The data on the B use efficiency of the two field experiment are presented in Table. It is evident from the data that in the first crop, the highest value of 124.48 was noticed in B_1 (2.5 kg B ha^{-1}) and showed a decreasing trend with increase in the level. The lowest value recorded was that of B_2 (5.0 kg B ha^{-1}) as 41.15 and was only 4.6 per cent more than B_3 (7.5 kg B ha^{-1}).

In the second crop also, the same trend was observed and the highest value of 110.04 was shown by B_1 (2.5 kg B ha^{-1}). The lowest value of 36.72 was recorded by B_2 (5.0 kg B ha^{-1}).

Table 25. S use efficiency and Apparent S Recovery

Levels of S (kg ha^{-1})	S Use Efficiency		Apparent S Recovery	
	I Crop	II Crop	I Crop	II Crop
7.5	3.91	2.33	45.33	48.40
15	6.68	5.8	36.93	46.40
30	8.33	9.26	27.30	33.43

Table 26. B Use Efficiency and Apparent B Recovery

Levels of B (kg ha^{-1})	B Use Efficiency		Apparent B Recovery	
	I crop	II Crop	I Crop	II Crop
2.5	124.48	110.04	26.90	38.04
5.0	41.15	36.72	36.02	46.11
7.5	43.14	42.14	35.68	35.64

4.2.7.4 Apparent B Recovery

It is explicit from the data that the highest value of 36.02 per cent was observed in B_2 (5 kg B ha^{-1}). The lowest value of 26.90 per cent was observed in B_1 (2.5 kg B ha^{-1}).

In the second field experiment also, the same trend was observed and the highest value of 46.11 per cent was recorded by B_2 (5 kg B ha^{-1}). The lowest value observed was 35.64 per cent being shown by B_3 (7.5 kg B ha^{-1}).

4.2.8 Soil (Table 27 a and b to 29 a and b)

The data on available nutrient status of the soil sampled at the harvest of the crop growth are presented in this section.

4.2.8.1 Organic carbon

Statistical analysis of the data pertaining to the first crop revealed that the treatments had significant effect on the organic carbon content of the soil. In the case of the interaction effect, the highest value 0.479 per cent was recorded by the T_{16} (S_3B_3) which received S and B @ 30 and 7.5 kg ha^{-1}respectively. The lowest value of 0.245 per cent was recorded by T_1 (S_0B_0).

It is evident from the data that the different levels of S and B had also significant effect on the organic carbon status of the soil. Among the S levels, S_3 (30.0 kg S ha^{-1}) recorded the highest value of 0.376 per cent and the lowest of 0.259 per cent was shown by S_0. But among the levels of B, B_3 (7.5 kg B ha^{-1}) recorded the highest value of 0.307 per cent and B_0 (0.0 kg B ha^{-1}) showed the lowest value of 0.300 per cent.

It is evident from the data that the interaction between S and B was significant for the organic carbon content of the soil in the second crop. The highest value of 0.399 per cent was recorded by T_{16} (S_3B_3) which was on par with T_{15} (0.385%). The lowest value of 0.207 per cent was recorded by T_1 (S_0B_0).

As regard to the individual effects of different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the significantly superior values of 0.381 per cent and 0.318 per cent respectively. The lowest values recorded were 0.217 per cent and 0.257 per cent being shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.2.8.2 Available nitrogen

Perusal of the data showed that the interaction between different levels of S and B could registered significant effect on the available N status of the soil in the first field experiment. The highest value of 257.15 kg ha^{-1} was recorded by T_{16} (S_3B_3) followed by T_{15} (S_3B_2) and the lowest value of 75.50 kg ha^{-1} was recorded by T_1 (S_0B_0).

Application of S at various levels significantly increased the available nitrogen content of the soil. S_3 (30.0 kg S ha^{-1}) recorded the highest value of 228.89 kg ha^{-1} and was on par with S_2. The lowest value of 113.61 kg ha^{-1} was shown by S_0 (0 kg ha^{-1}). However the effect of B levels were not significant. The values varied between 152.95 kg ha^{-1} and 195.65 kg ha^{-1} being shown by B_0 (0.0 kg B ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively.

In the second crop, the levels of S and B and their interaction significantly influenced the available nitrogen content of the soil.T_{16} (S_3B_3) recorded the highest value of 279.80 kg ha^{-1} followed by T_{15} (S_3B_2) which were on par with each other. The lowest value of 120.50 kg ha^{-1} was recorded by T_1 (S_0B_0) preceded by T_2 (S_0B_1) and were on par.

Coming to the main effects of S and B, the available N content increased with increasing levels of S and B. Among the levels of S, S_3 (30.0 kg ha^{-1}) recorded the significantly superior value of 241.14 kg ha^{-1} followed by S_2. The lowest value of 169.03 kg ha^{-1} was recorded by S_0. B_3 (7.5 kg B ha^{-1}) recorded the superior value of 227.59 kg ha^{-1} among the different levels of B and was on par with B_2 (5 kg B ha^{-1}). The lowest value of 165.61 kg ha^{-1}was recorded by B_0 (0.0 kg B ha^{-1}).

Table 27 a. Available nutrient status of soil at harvest of the first crop

Treatments	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	EC (d Sm^{-1})	pH
$S_0 B_0$	0.245	75.50	7.50	62.74	0.300	4.95
$S_0 B_1$	0.252	102.04	10.40	101.92	0.300	5.40
$S_0 B_2$	0.260	129.28	12.20	122.08	0.200	5.25
$S_0 B_3$	0.280	147.60	17.10	128.80	0.150	5.55
$S_1 B_0$	0.295	152.10	18.10	123.50	0.350	4.20
$S_1 B_1$	0.298	189.73	22.00	140.00	0.250	4.90
$S_1 B_2$	0.409	211.68	22.60	142.54	0.150	5.15
$S_1 B_3$	0.418	213.28	21.40	155.00	0.250	5.55
$S_2 B_0$	0.402	170.91	21.70	132.16	0.200	5.05
$S_2 B_1$	0.413	171.24	20.50	141.68	0.200	5.30
$S_2 B_2$	0.425	193.49	21.90	143.06	0.200	5.60
$S_2 B_3$	0.436	210.12	21.80	166.50	0.300	5.35
$S_3 B_0$	0.458	213.28	23.80	137.60	0.200	5.65
$S_3 B_1$	0.470	222.66	24.70	196.32	0.200	5.35
$S_3 B_2$	0.479	222.90	25.40	196.00	0.200	5.15
$S_3 B_3$	0.495	257.15	25.50	204.48	0.200	5.90
S_0	0.259	113.61	11.88	103.89	0.238	5.29
S_1	0.305	191.70	21.02	140.26	0.250	4.95
S_2	0.319	186.44	21.48	145.85	0.2250	5.33
S_3	0.376	228.99	24.85	183.60	0.200	5.51
B_0	0.300	152.95	17.78	114.00	0.263	5.04
B_1	0.308	178.23	19.40	144.98	0.238	5.24
B_2	0.343	193.92	20.53	150.92	0.188	5.29
B_3	0.307	195.65	21.45	163.70	0.225	5.59
F-S	4.28*	27.33**	7.61**	4.78*	0.439^{NS}	3.96*
F-B	4.65*	2.70^{NS}	1.72^{NS}	5.95**	0.9398^{NS}	4.83*
F-S.B	2.67*	2.83*	5.16**	4.75**	0.8730^{NS}	2.75*
CD - S	0.0565	27.82	2.44	32.82	-	0.350
CD - B.	0.0565	-	-	32.82	-	0.350
CD - S.B	0.1130	55.65	4.88	65.65	-	0.700

Table 27 b. Available nutrient status of soil at harvest of the second crop

Treatments	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	pH	EC (dSm^{-1})
$S_0 B_0$	0.207	120.50	6.50	65.40	4.95	0.3000
$S_0 B_1$	0.212	155.70	9.45	108.60	5.40	0.3000
$S_0 B_2$	0.220	189.50	10.26	133.75	5.25	0.2000
$S_0 B_3$	0.229	210.40	15.10	149.05	5.55	0.2000
$S_1 B_0$	0.250	165.04	16.66	116.65	4.20	0.5000
$S_1 B_1$	0.265	167.50	20.00	134.33	4.90	0.2500
$S_1 B_2$	0.285	173.85	21.60	149.00	5.15	0.1500
$S_1 B_3$	0.295	207.45	20.40	157.55	5.55	0.2500
$S_2 B_0$	0.210	169.30	20.70	125.50	5.05	0.2000
$S_2 B_1$	0.328	179.45	18.80	132.70	5.30	0.2000
$S_2 B_2$	0.335	183.35	19.90	140.50	5.60	0.2000
$S_2 B_3$	0.349	212.70	19.80	171.45	5.35	0.3000
$S_3 B_0$	0.362	207.60	21.80	138.45	5.65	0.2000
$S_3 B_1$	0.379	229.30	22.90	160.45	5.35	0.2000
$S_3 B_2$	0.385	247.85	23.80	162.50	5.15	0.20
$S_3 B_3$	0.399	279.80	23.90	172.00	5.90	0.2000
S_0	0.217	169.03	10.33	114.20	5.29	0.2500
S_1	0.274	178.46	19.67	139.38	4.95	0.2875
S_2	0.306	186.20	19.80	142.54	5.33	0.2250
S_3	0.381	241.14	23.10	158.35	5.51	0.2000
B_0	0.257	165.61	16.42	115.50	4.96	0.3000
B_1	0.296	182.99	17.79	134.02	5.24	0.2375
B_2	0.306	198.64	18.89	146.44	5.29	0.1875
B_3	0.318	227.59	19.80	162.51	5.59	0.2375
F-S	17.0857**	20.99**	7.45**	4.34*	4.04*	0.6764^{NS}
F-B	3.83*	4.13*	1.01^{NS}	12.45**	4.83*	1.0303^{NS}
F-S.B	2.77*	3.99**	8.86**	5.45**	1.75^{NS}	0.7944^{NS}
CD - S	0.1921	21.307	1.523	16.209	0.4855	-
CD - B.	0.1921	21.307	-	16.209	0.4855	-
CD - S.B	0.3841	42.613	3.046	32.418	-	-

4.2.8.3 Available phosphorus

The interaction between S and B was significant on the P content of the soil. T_{16} (S_3B_3) registered the highest value of 25.50 kg ha^{-1} and was on par with T_{15} (S_3B_2) and T_{14}. The lowest value of 7.50 kg ha^{-1} was recorded by T_1 (S_0B_0) followed by T_2 (S_0B_1) which were on par.

As for the individual effects of S and B, the available P content of the soil was significantly influenced by the application of different levels of S. S_3 (30.0 kg ha^{-1}) recorded highest value of 24.85 kg ha^{-1} followed by S_2. The phosphorus content of the soil showed an increasing trend with increasing levels of B and B_3 (7.5 kg B ha^{-1}) showed the highest value of 21.45 kg ha^{-1}. The lowest values of 11.80 and 17.78 kg ha^{-1} was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

In the second field experiment, the trend was similar to that of the first crop. The interaction between S and B was also significant for the P content in soil and the highest value of 23.90 kg ha^{-1} was recorded by T_{16} (S_3B_3) which was on par with T_{15} (S_3B_2). This was followed by T_{14} (S_3B_1). The lowest value of 6.50 kg ha^{-1} was recorded by T_1 (S_0B_0) preceded by T_2. Increasing levels of S and B showed an increasing trend for available P which was similar to that of the first crop.

Significant effect was registered only with regard to the individual effect of S. S_3 (30.0 kg S ha^{-1}) was significantly superior to the other levels and recorded a value of 23.10 kg ha^{-1} followed by S_2 (19.80 kg S ha^{-1}). The lowest value was recorded by S_0 as 10.33 kg ha^{-1}. Among the levels of B, B_3 (7.5 kg B ha^{-1}) recorded the highest value of 19.80 kg ha^{-1} followed by B_2 (5.0 kg B ha^{-1}) and were on par with each other. The lowest value of 16.42 kg ha^{-1} was recorded by B_0 (0.0 kg B ha^{-1}).

4.2.8.4 Available potassium

Perusal of the data regarding the first crop revealed that the available K content of the soil was significantly influenced by the application of S and B. T_{16} (S_3B_3) recorded the highest value of 204.48 kg ha^{-1} which was significantly superior to all other treatments. This was followed by T_{15} (S_3B_2) and T_{14} (S_3B_1) which were on par with each other. The lowest value of 62.74 kg ha^{-1} was shown by T_1 (S_0B_0).

The levels of S and B individually were also significant for the available K status of the soil. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the superior levels and they showed the values of 183.60 kg ha^{-1} and 163.70 kg ha^{-1} respectively. The lowest values of 103.89 kg ha^{-1} and 114.00 kg ha^{-1} were recorded by S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

In the second crop, significant effect of the interaction between S and B was noticed. T_{15} (S_3B_2) showed the highest value of 172 kg ha^{-1} and was on par withT_{16} (S_3B_3) and T_{11} (S_2B_2). The lowest value of 65.40 kg ha^{-1} was recorded by T_1 (S_0B_0) which received no S and B.

The levels of S and B individually also registered significant effect on the available K status of the soil. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the superior values of 158.85 kg ha^{-1} and 165.21 kg ha^{-1} respectively. The lowest value of 114.20 kg ha^{-1} was recorded by S_0. Among the levels of B, B_0 (0.0 kg B ha^{-1}) recorded the lowest value of 115.50 kg ha^{-1}.

4.2.8.5 pH

Critical evaluation of the data concerning the first crop revealed the significant influence of the interaction between different levels of S and B and their individual effects upon soil pH. Among the interaction effect, T_{16} (S_3B_3) recorded the highest value of 5.90 followed by T_{13}(S_3B_0) and were on par with each other. The lowest value recorded was 4.20 shown by T_5(S_1B_0).

Regarding the individual effects of different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 5.51 and 5.59 respectively. The lowest values of 4.95 and 5.04 were shown by S_1 (7.5 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

In the case of the second crop, the interaction between different levels of S and B were not found to be significant. As in the case of the first crop, the values ranged from 4.20 to 5.90 recorded by T_5 (S_1B_0) and T_{16}(S_3B_3) respectively.

Among the different levels of S and B, S_3 (30.0 kg S ha^{-1}) recorded the highest value of 5.51 and the lowest value of 4.95 was shown by S_1 (7.5 kg S ha^{-1}). B_3 (7.5 kg B ha^{-1}) recorded the highest value of 5.59 and was on par with B_2 (5.0 kg B ha^{-1}) with the value of 5.29. The lowest value of 4.96 was recorded by B_0 (0.0 kg B ha^{-1}).

4.2.8.6 Electrical conductivity

In the first crop, it had been observed that the interaction between different levels of S and B and their individual effects could not register any significance with regard to the electrical conductivity. The values ranged between 0.15 dSm^{-1} and 0.3 dSm^{-1} recorded by T_4 (S_0B_3) and T_5 (S_1B_0).

Among the different levels of S and B, S_1 (7.5 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) showed the highest values of 0.250 dSm^{-1} and 0.263 dSm^{-1} respectively. The lowest values of 0.20 $dSm^{-1}$and 0.188 dSm^{-1}were recorded by S_3 (30.0 kg S ha^{-1}) and B_2.

In the second crop also, no significance due to the interaction between different levels of the nutrients had been found. Here the values ranged between 0.15 dS $m^{-1}$and 0.59 dS m^{-1}shown by T_7 (S_1B_2) and T_5 (S_1B_0) respectively.

With regard to the individual effects of S and B, S_1 (7.5 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) recorded the highest values of 0.2875 dSm^{-1} and 0.300 dSm^{-1} among the different levels of S and B. The lowest values of 0.200 d Sm^{-1} and 0.1875 dSm^{-1} were shown by S_3 (30.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

4.2.8.7 Exchangeable calcium

Statistical analysis of the data of the first crop revealed that S and B application had significant effect on the exchangeable Ca status of the soil. T_{13} (S_3B_0) recorded the highest value of 0.975 c mol kg^{-1}which was on par with T_{11}

(S_2B_2) and T_{16} (S_3B_3). The lowest value of 0.285 c mol kg^{-1} was shown by the treatment which received no S or B T_1 (S_0B_0).

Increasing levels of S showed increasing trend for the Ca content of the soil. S_3 (30.0 kg ha^{-1}) recorded the highest value of 0.85 c mol kg^{-1}. Among the levels of B, B_2 (5.0 kg B ha^{-1}) recorded the significantly highest value of 0.75 cmol kg^{-1} followed by B_3. The lowest values of 0.452 c mol $kg^{-1}$and 0.450 c mol kg^{-1}were shown by S_0 (0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively.

The levels of S and B and their interaction were highly significant for the exchangeable Ca content of the second crop as depicted in table. The interaction between S and B levels also showed high significance on the exchangeable Ca content of the second crop and the highest value of 1.05 c mol $kg^{-1}$was produced by T_{13}(S_3B_0) (S_3B_0). All the treatments were significantly lower than it and this was followed by T_9 (S_2B_0). The lowest value of 0.370 c mol $kg^{-1}$was recorded by T_3(S_0B_2), preceded by T_4(S_0B_3).

Coming to the individual effects of these nutrients, S_3 (30.0 kg S ha^{-1}) recorded the significantly highest value of 0.919 cmol kg^{-1} followed by S_2 (15.0 kg S ha^{-1}) and the lowest value of 0.450 c mol kg^{-1} was recorded by S_0. All the treatments were significantly superior to other levels of S. B_0 (0.0 kg B ha^{-1}) recorded the highest value of 0.838 c mol kg^{-1} followed by B_1 (2.5 kg B ha^{-1}) which shows that as the level of applied B increased, the Ca content in soil decreased. The lowest value of 0.668 c mol $kg^{-1}$was recorded by B_2 (5.0 kg B ha^{-1}).

4.2.8.8 Exchangeable magnesium

In the first crop, the interaction of S and B showed a significant effect on the exchangeable Mg content of the soil. Perusal of the data indicated a gradual decrease in the content of the nutrient with increasing levels of S and B. The highest value of 0.325 c mol kg^{-1} was registered in T_{10} (S_2B_1) followed by T_9

Table 28 a. Exchangeable Ca, Mg and available S and B status of soil at harvest of the first crop

Treatments	Exch. Ca (cmol kg^{-1})	Exch. Mg (cmol kg^{-1})	Available S (kg ha^{-1})	Available Boron(ppm)
$S_0 B_0$	0.285	0.0170	20.00	0.259
$S_0 B_1$	0.465	0.0900	25.60	0.350
$S_0 B_2$	0.533	0.1580	24.98	0.393
$S_0 B_3$	0.525	0.1750	26.50	0.486
$S_1 B_0$	0.300	0.0530	36.20	0.263
$S_1 B_1$	0.608	0.1100	32.00	0.717
$S_1 B_2$	0.750	0.1280	35.00	1.100
$S_1 B_3$	0.510	0.2500	34.00	1.640
$S_2 B_0$	0.600	0.0450	38.00	0.392
$S_2 B_1$	0.788	0.1250	39.25	1.080
$S_2 B_2$	0.929	0.2900	33.67	1.360
$S_2 B_3$	0.660	0.3250	40.52	1.790
$S_3 B_0$	0.975	0.0600	42.83	0.356
$S_3 B_1$	0.765	0.1100	46.22	1.068
$S_3 B_2$	0.638	0.1880	40.00	1.675
$S_3 B_3$	0.862	0.2180	44.00	2.210
S_0	0.452	0.1120	24.27	0.372
S_1	0.461	0.1350	34.29	0.930
S_2	0.622	0.1960	37.86	1.160
S_3	0.850	0.1440	43.06	1.327
B_0	0.540	0.0438	34.25	0.318
B_1	0.450	0.1090	35.21	0.804
B_2	0.750	0.1910	33.41	1.130
B_3	0.640	0.2420	38.33	1.530
F-S	1.60^{NS}	2.79^{NS}	3.41**	7.08**
F-B	5.18**	2.11^{NS}	17.21**	5.23*
F-S.B	2.89*	5.67**	9.67**	11.70**
CD - S	-	-	5.100	0.349
CD - B.	0.173	-	5.100	0.349
CD - S.B	0.346	0.12901	10.20	0.698

Table 28 b Exchangeable Ca, Mg and available S and B status of soil at harvest of the second crop

Treatments	Exch. Ca (cmol kg^{-1})	Exch. Mg (c mol kg^{-1})	Available S (kg ha^{-1})	Available Boron(ppm)
$S_0 B_0$	0.510	0.0225	16.55	0.320
$S_0 B_1$	0.510	0.3050	17.55	0.716
$S_0 B_2$	0.370	0.1650	24.45	1.230
$S_0 B_3$	0.410	0.2650	25.95	1.720
$S_1 B_0$	0.855	0.3950	30.60	0.405
$S_1 B_1$	0.730	0.3100	26.90	1.100
$S_1 B_2$	0.670	0.2550	38.85	1.470
$S_1 B_3$	0.775	0.2100	31.95	1.690
$S_2 B_0$	0.935	0.4700	45.50	0.465
$S_2 B_1$	0.815	0.3900	40.40	0.830
$S_2 B_2$	0.755	0.3400	44.00	1.530
$S_2 B_3$	0.740	0.1900	41.95	2.160
$S_3 B_0$	1.05	0.2250	50.75	0.473
$S_3 B_1$	0.905	0.2400	47.0	0.889
$S_3 B_2$	0.875	0.2650	45.60	1.160
$S_3 B_3$	0.845	0.4400	53.40	2.270
S_0	0.450	0.1894	21.25	0.997
S_1	0.758	0.2925	32.08	1.170
S_2	0.811	0.3475	42.96	1.200
S_3	0.919	0.2925	49.19	1.250
B_0	0.838	0.2781	35.85	0.416
B_1	0.740	0.3113	32.96	0.884
B_2	0.668	0.2563	38.25	1.35
B_3	0.693	0.2763	38.31	1.96
F-S	200.61**	49.05**	11.64**	5.1566 **
F-B	27.94**	5.84**	13.94**	3.75*
F-S.B	3.12*	41.19**	6.60**	6.56**
CD - S	0.05917	0.03929	5.818	0.36479
CD - B.	0.05917	0.03929	5.818	0.36479
CD - S.B	0.1180	0.07859	11.637	0.7950

(S_2B_0) and were on par with each other. The lowest value of 0.017 c mol kg^{-1} was recorded by T_1 (S_0B_0).

The levels of S and B individually were not significant for the exchangeable Mg content of the soil. Among the levels of S, S_2 (15.0 kg S ha^{-1}) recorded the highest value of 0.196 c mol kg^{-1} followed by S_3 (0.144 c mol kg^{-1}). B_1 (2.5 kg B ha^{-1}) recorded the highest value of 0.184 c mol kg^{-1} followed by B_0 (0.0 kg ha^{-1}). The lowest values of 0.112 c mol $kg^{-1}$and 0.110 c mol kg^{-1}were shown by S_0 (0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively.

In the second crop application of S and B had significant effect on the exchangeable Mg content of the soil. T_9 (S_2B_0) recorded the highest value of 0.470 c mol kg^{-1} followed by T_{16} (0.44) and were on par. The lowest value of 0.220 c mol $kg^{-1}$was recorded by T_1 (S_0B_0) and all the treatments were significantly higher than T_1.

As for the main effects of S and B, S_2 (15.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) recorded the highest value among the levels of S and B which were 0.3475 c mol kg^{-1} and 0.3113 c mol kg^{-1} respectively and were significantly superior to the other levels. The lowest value of 0.1894 c mol kg^{-1} and 0.2563 c mol kg^{-1}were showed by S_0 (0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively.

4.2.8.9 Available sulphur

Statistical analysis of the data indicated that S and B had significant effect on the available S status of the soil. The interaction effect of S and B was significantly influenced the available S content. T_{14}(S_3B_1) recorded the highest value of 46.22 kg ha^{-1} followed by T_{16}(S_3B_3), T_{13}(S_3B_0) and T_{15}(S_3B_2) which were on par and the lowest value of 20 kg ha^{-1} was shown by T_1 (S_0B_0).

As the level of S increased from 0 to 30 kg ha^{-1}, the S content of the soil also gradually increased. The highest value of 43.06 kg ha^{-1} was recorded by S_3 (30.0 kg S ha^{-1}) which was significantly superior to the other levels. The lowest value of 24.27 kg ha^{-1} was shown by S_0. Among the B levels, the highest value 38.33 kg ha^{-1} was shown by B_3 (7.5 kg B ha^{-1}) followed by B_2 (5.0 kg B ha^{-1})

which were on par. The lowest value of 34.25 kg ha^{-1} was shown by B_0 (0.0 kg ha^{-1}).

In the second field experiment also, the trend was repeated and the levels of S and B and their interaction significantly influenced the available S content of the soil. Significant effect of the interaction between S and B has been statistically observed and the highest value of 53.40 kg ha^{-1} was shown by $T_{16}(S_3B_3)$ which was on par with $T_{13}(S_3B_0)$, $T_{14}(S_3B_1)$, $T_{15}(S_3B_2)$ and T_9 (S_2B_0) and the lowest value of 16.55 kg ha^{-1} was shown by T_1 (S_0B_0) preceded by $T_4(S_0B_3)$, both of which received no S.

Increasing levels of S and B showed an increasing trend for the S content of the soil. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the significantly superior values of 49.19 kg ha^{-1} and 38.31 kg ha^{-1} respectively and were followed by S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}). The lowest value was recorded by S_0 (21.25 kg S ha^{-1}) and B_1 (32.96 kg B ha^{-1}) respectively.

4.2.8.10 Hot water extractable B

The critical examination of the data of the first crop revealed that the interaction between different levels of S and B registered significant effect on the B content of soil. The highest value of 2.21 ppm was recorded by T_{16} (S_3B_3) which received B@7.5 kg ha^{-1} and S @ 30 kg ha^{-1} followed by T_8 (S_1B_3). T_{16} (S_3B_3) was significantly superior to all other treatments. The lowest value of 0.259 ppm was shown by T_1 (S_0B_0) which was on par with T_2 (S_0B_1). A gradual increase in B content with increase in the applied level was observed in the study.

Application of different levels of S and B had significant effect on the B status of soil. Among the different levels of S applied, S_3 (30.0 kg S ha^{-1}) recorded the highest value of 1.327 ppm followed by S_2 (1.16 ppm). S_0 (0 kg S ha^{-1}) showed the lowest value of 0.372 ppm. The levels of B had also significant effect on the B content and the highest value of 1.53 ppm was recorded by B_3 (7.5 kg B ha^{-1}) and was on par with B_2 (5.0 kg B ha^{-1}). The lowest value of 0.318 ppm was shown by B_0 (0.0 kg B ha^{-1}).

In the second crop also, the trend was repeated such that application of B at higher levels showing high values irrespective of the S levels. Perusal of the data showed that the interaction of S and B were also significant for the available B content of the soil and the highest value of 2.27 ppm was noticed with T_{16} (S_3B_3) which was on par with T_{12} (S_2B_3), T_4 (S_0B_3), T_8(S_1B_3) and T_{11}. The lowest value of 0.320 ppm was produced by T_1 (S_0B_0).

The levels of S and B had significant effect on the available B content of the soil and the highest value of 1.25 ppm and 1.96 ppm was shown by S_3 (30 kg S ha^{-1}) and B_3. The lowest value in both case was noticed as 0.997 ppm and 0.416 ppm respectively produced by S_0 (0.0 kg S ha^{-1}) and B_0 (0.0 kg S ha^{-1}) respectively.

4.2.8.11 DTPA Extractable Micronutrients

4.2.8.11.1 Iron

Application of treatments had a significant effect on the iron content of soil. The interaction of S and B was significant for the Fe content of the soil. The highest value of 44 ppm was recorded by T_8 (S_1B_3) followed by T_{13} (S_3B_0) and T_{16} (S_3B_3) which were on par and the lowest value of 10.62 ppm was recorded by T_1 (S_0B_0).

Among the different levels of S, S_3 (30.0 kg S ha^{-1}) recorded the highest value of 40.07 ppm and the lowest value was recorded by S_0 (21.96 ppm). Significant effect of different levels of B was also noted in the study and the highest value of 35.05 ppm was recorded by B_3 (7.5 kg B ha^{-1}). The lowest value of 22.74 ppm was shown by B_1 (2.5 kg B ha^{-1}).

In the second crop, perusal of the data showed that application of different levels of S and B had a significant effect on the Fe content of the soil. The interaction between different levels of S and B also showed significant effect. The values ranged from 13.30 ppm to 53.95 ppm recorded by T_1 (S_0B_0) and T_{11} (S_2B_2) respectively. T_{11} (S_2B_2) was significantly superior to other treatments.

Among the levels of S, the values ranged from 27.55 ppm to 38.83 ppm recorded by S_1 (7.5 kg S ha^{-1}) and S_3 (30.0 kg S ha^{-1}) respectively. S_3 (30.0 kg ha^{-1}) was significantly superior to the other levels. In the case of B, the values ranged from 23.73 ppm to 38.00 ppm shown by B_0 (0.0 kg B ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively. B_2 (5.0 kg B ha^{-1}) was on par with B_3.

4.2.8.1.2 Manganese

The Mn content of the soil was significantly influenced by the application of S and B. The interaction effect of S and B registered significant effect for the parameter. The highest value of 4.33 ppm was recorded by $T_{13}(S_3B_0)$ followed by T_{11} (S_2B_2) and $T_{10}(S_2B_1)$ which were on par. The lowest value of 1.71 ppm was recorded by T_{12} (S_2B_3).

Perusal of the data showed that S_3 (30.0 kg S ha^{-1}) recorded the highest value of 3.03 ppm followed by S_2 (15.0 kg S ha^{-1}) which were on par with each other. The lowest value was shown by S_1 (2.22 ppm). Among the levels of B, B_1 (2.5 kg B ha^{-1}) recorded the highest value of 2.91 ppm followed by B_2 (5.0 kg B ha^{-1}) and they were on par and B_3 (7.5 kg B ha^{-1}) recorded the lowest value (1.93 ppm).

In the second field experiment, the levels of S and B were significant on the Mn content of the soil. The interaction between S and B were significant and the highest value was recorded by T_{11} (S_2B_2) followed by $T_{13}(S_3B_0)$ and were on par. The lowest value was produced by T_4 (S_0B_3). The values ranged between 1.53 ppm and 4.32 ppm.

Among the levels of S even though no definite trend was observed on the Mn content of the soil, the values ranged between 2.51 and 3.15 ppm recorded by S_1 (7.5 kg S ha^{-1}) and S_2 (15.0 kg S ha^{-1}) respectively. Among the different levels of B, the values ranged between 1.88 ppm and 3.13 ppm recorded by B_3 (7.5 kg B ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively.

4.2.8.1.3 Copper

In the first field experiment perusal of the data shows that the application of S and B had no significant effect on the DTPA extractable Cu content of soil.

Table 29a. DTPA Extractable micronutrient status of soil at harvest of the first crop

Treatments	Fe(ppm)	Mn(ppm)	Cu(ppm)	Zn(ppm)
$S_0 B_0$	10.62	2.15	0.300	Traces
$S_0 B_1$	14.60	3.04	0.375	1.320
$S_0 B_2$	31.00	2.31	0.431	1.410
$S_0 B_3$	31.63	2.15	0.770	1.390
$S_1 B_0$	21.40	1.96	0.611	0.874
$S_1 B_1$	14.14	2.23	0.690	1.070
$S_1 B_2$	34.00	2.58	0.800	1.480
$S_1 B_3$	44.00	2.11	0.900	1.230
$S_2 B_0$	20.16	2.60	0.580	1.240
$S_2 B_1$	23.70	3.55	0.360	0.740
$S_2 B_2$	30.00	4.25	0.360	1.260
$S_2 B_3$	21.20	1.71	0.360	0.875
$S_3 B_0$	43.20	4.33	0.580	0.760
$S_3 B_1$	38.51	2.82	0.690	1.240
$S_3 B_2$	43.20	1.90	0.780	1.840
$S_3 B_3$	43.36	1.75	0.450	1.270
S_0	21.96	2.41	0.469	1.210
S_1	28.39	2.22	0.750	1.160
S_2	23.77	3.03	0.590	0.845
S_3	40.07	2.70	0.625	1.280
B_0	23.85	2.76	0.518	0.904
B_1	22.74	2.91	0.529	0.908
B_2	34.55	2.76	0.768	1.500
B_3	35.05	1.93	0.620	1.190
F-S	20.98**	4.64*	1.77^{NS}	8.13**
F-B	12.80**	8.45**	1.92^{NS}	17.54**
F-S.B	12.85**	8.43**	1.66^{NS}	7.26**
CD - S	5.88	0.463	-	0.202
CD - B.	5.88	0.463	-	0.202
CD - S.B	11.76	0.926	-	0.404

Table 29 b. DTPA Extractable micronutrient status of soil at harvest of the second crop

Treatments	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)
$S_0 B_0$	13.30	2.52	0.1235	0.405
$S_0 B_1$	35.80	3.23	0.1240	1.305
$S_0 B_2$	30.20	2.80	0.2820	1.330
$S_0 B_3$	30.90	1.53	0.6850	1.220
$S_1 B_0$	24.70	2.23	0.5090	0.890
$S_1 B_1$	14.80	2.60	0.6470	1.020
$S_1 B_2$	29.25	2.65	0.9000	1.370
$S_1 B_3$	40.25	2.56	0.7890	1.330
$S_2 B_0$	26.40	2.95	0.7330	1.330
$S_2 B_1$	13.50	3.69	0.2960	0.570
$S_2 B_2$	53.95	4.32	0.8060	1.260
$S_2 B_3$	21.25	1.62	0.3750	0.910
$S_3 B_0$	30.50	3.91	0.5850	0.805
$S_3 B_1$	41.80	3.00	0.7420	1.260
$S_3 B_2$	38.60	2.04	0.7410	1.800
$S_3 B_3$	44.40	1.80	0.4720	1.280
S_0	27.55	2.52	0.3040	1.110
S_1	27.25	2.51	0.7110	1.510
S_2	28.76	3.15	0.6160	0.9750
S_3	38.83	2.68	0.6350	1.280
B_0	23.73	2.90	0.4870	0.898
B_1	26.48	3.13	0.4520	0.996
B_2	38.00	2.95	0.7180	1.440
B_3	34.20	1.88	0.6080	1.180
F-S	6.76**	5.53**	19.62**	13.90**
F-B	8.51**	3.53*	8.89**	48.30**
F-S.B	5.81**	5.17**	9.17**	21.36**
CD - S	6.853	0.5437	0.12240	0.1030
CD - B.	6.853	0.5437	0.12240	0.1030
CD - S.B	13.706	1.088	0.24480	0.2060

Perusal of the data showed that the interaction between S and B were not significant for the Cu content of the soil. The highest value was recorded by T_8 (S_1B_3) and the lowest value of 0.3 ppm was shown by T_1 (S_0B_0).

With regard to the individual effects of different levels of S and B, S_1 (7.5 kg S ha^{-1}) recorded the highest value of 0.750 ppm among the levels of S and B_2 (5.0 kg B ha^{-1}) recorded the highest value of 0.768 ppm among the levels of B. The lowest values of 0.469 ppm and 0.518 ppm were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

In the second field experiment, the treatment effects were significant and the trend was same as that in the first crop. The interaction between different levels of S and B were significant and the values ranged between 0.900 and 0.124 recorded by T_7 (S_1B_2) and T_1 (S_0B_0) respectively.

In the case of S, S_1 (7.5 kg S ha^{-1}) recorded the highest value of 0.711 ppm followed by S_3 (0.635 ppm). B_2 (5.0 kg B ha^{-1}) was the superior level for B followed by B_3 (7.5 kg B ha^{-1}) and were on par with each other recording the values 0.718 ppm and 0.608 ppm respectively. The lowest value of 0.452 ppm was shown by B_1 (2.5 kg B ha^{-1}).

4.2.8.4 Zinc

The content of DTPA extractable Zn was significantly influenced by the application of S and B. The interaction effect of S and B had significant effect on the Zn content of the soil. T_{15} (S_3B_2) recorded the highest value of 1.84 ppm followed by T_7 (S_1B_2) and T_3(S_0B_2) all of which were on par and only trace amount was observed in T_1 (S_0B_0).

As for the main effects of different levels of S and B, the lowest values of 0.845 ppm was recorded by S_2 (15.0 kg S ha^{-1}). S_3 (30.0 kg S ha^{-1}) recorded the highest value of 1.28 ppm among the different levels of S and was on par with S_1. Among the levels of B, the values ranged between 0.904 ppm and 1.50 ppm recorded by B_0 (0.0 kg B ha^{-1}) and B_2 (5.0 kg B ha^{-1}) respectively.

Statistical analysis of the data showed significant effect of the interaction between different levels of S and B and the values ranged between 0.405 ppm and 1.80 ppm recorded by T_1 (S_0B_0) and T_{15} (S_3B_2) respectively. All the treatments were significantly lower than T_{15} (S_3B_2) with regard to Zn content of the crop.

Similar trend was observed in the second crop also. For the levels of S and B the treatment effects were highly significant and the highest value of 1.28 ppm was shown by S_3 (30.0 kg S ha^{-1}) and the lowest value of 0.975 ppm was produced by S_2. B_2 (5.0 kg B ha^{-1}) showed the highest value of 1.44 ppm in the case of B and the lowest value of 0.898 ppm was recorded by B_0 (0.0 kg B ha^{-1}).

4.3 TISSUE NUTRIENT CONCENTRATION AT DIFFERENT SAMPLING STAGES

4.3.1 Sulphur

The data on the S content of the different parts of the plant such as lamina, petiole, midrib and internode sampled at 20 DAS, 30 DAS, 40 DAS, and 50 DAS are presented in Table 30 to 37.

Statistical analysis of the data reveals that application of treatments had a significant effect upon the S content of these parts at the different growth stages. In all the parts at all the sampling stages, the S content was found to be increasing with increasing level of nutrient application from 0 to 30 kg ha^{-1} At all stages, T_{16} (S_3B_3) was the superior treatment followed by T_{15}(S_3B_2) and T_{14}(S_3B_1).

Considering individual effects, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the significantly superior levels in all the four stages.

4.3.1.1 20 DAS (Table 30)

4.3.1.1.1 Lamina

A positive influence of the application of S and B was recorded in all the plant parts and of which, the lamina recorded the highest values. The highest value of 0.327 per cent was recorded by T_{16} (S_3B_3) followed

Table 30. S content of plant parts at 20DAS (%)

Treatments	Lamina	Petiole	Midrib	Internode
$S_0 B_0$	0.0603	0.0141	0.0660	0.0398
$S_0 B_1$	0.108	0.0423	0.0715	0.0440
$S_0 B_2$	0.126	0.0609	0.0945	0.0476
$S_0 B_3$	0.156	0.0548	0.1460	0.0485
$S_1 B_0$	0.166	0.0593	0.1700	0.0558
$S_1 B_1$	0.188	0.0630	0.1640	0.0571
$S_1 B_2$	0.170	0.1280	0.1710	0.0640
$S_1 B_3$	0.208	0.1630	0.1800	0.0582
$S_2 B_0$	0.250	0.1630	0.2030	0.0842
$S_2 B_1$	0.230	0.1530	0.2050	0.0636
$S_2 B_2$	0.226	0.1950	0.2340	0.0821
$S_2 B_3$	0.267	0.1740	0.2560	0.0831
$S_3 B_0$	0.263	0.1750	0.2520	0.0986
$S_3 B_1$	0.294	0.0930	0.2470	0.0985
$S_3 B_2$	0.308	0.1310	0.2470	0.0960
$S_3 B_3$	0.327	0.2660	0.2870	0.1070
S_0	0.113	0.0430	0.0944	0.0450
S_1	0.183	0.1030	0.1710	0.0588
S_2	0.243	0.1350	0.2250	0.0782
S_3	0.298	0.1660	0.2580	0.1000
B_0	0.184	0.1030	0.1710	0.0696
B_1	0.205	0.0877	0.1730	0.0658
B_2	0.208	0.0924	0.1870	0.0724
B_3	0.239	0.1640	0.2170	0.0742
F-S	89.91**	196.41**	165.49**	26.71**
F-B	7.29**	89.63**	14.58**	2.62^{NS}
F-S.B	3.19*	40.20**	3.58*	2.36^{NS}
CD - S	0.0253	0.01130	0.01670	0.01400
CD - B.	0.0253	0.01130	0.01670	-
CD - S.B	0.0506	0.02260	0.03340	-

by T_{15} (S_3B_2) and they were on par. The lowest value of 0.0603 per cent was shown by T_1 (S_0B_0).

Among the levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the superior values of 0.298 per cent and 0.239 per cent respectively. S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) recorded the lowest values of 0.113 and 0.184 per cent respectively.

4.3.1.1.2 Petiole

In the case of petiole, significant result had been obtained for the effect of different levels of S and B and the different treatment combinations. T_{16} (S_3B_3) was significantly superior to the other treatment combinations and recorded a value of 0.266 per cent. The lowest value of 0.0141 per cent was recorded by T_1 (S_0B_0) preceded by T_2 (S_0B_1).

With regard to the main effects of these nutrients, highest value of 0.166 per cent and 0.103 per cent was obtained with S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) followed by S_2 (15.0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively and they were significantly superior to the other levels. The lowest values of 0.0430 per cent and 0.0877 per cent were shown by S_0 (0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively.

4.3.1.1.3 Midrib

Statistical analysis of the data presented in Table shows that T_{16} (S_3B_3) recorded the highest value of 0.287 per cent T_{12} (S_2B_3) which was on par with it among the different treatment combinations. The lowest value was found in T_1 (S_0B_0) (0.066%).

S_3 (30.0 kg S ha^{-1}) was the significantly superior level among the different levels of S and B_3 (7.5 kg B ha^{-1}) was the one for B and these two recorded the values of 0.258 per cent and 0.217 per cent respectively. The lowest values of 0.0944 per cent and 0.171 per cent was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.3.1.1.4 Internode

Perusal of the data showed that T_{16} (S_3B_3) recorded the highest value (0.107%) followed by T_{13} (S_3B_0) and the lowest value of 0.0398 per cent was recorded by T_1 (S_0B_0).

S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the superior values among the different levels of S and B and the content was found to be 0.10 per cent and 0.0742 per cent respectively. The lowest value was shown by S_0 (0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) as 0.045 per cent and 0.0658 per cent respectively.

4.3.1.2 30 DAS (Table 31)

At 30 DAS, the trend was the same as in the case of 20 DAS and S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the superior levels for all the four parts analysed.

4.3.1.2.1 Lamina

Statistical analysis of the data revealed that even though, the interaction effect of S and B were not significant, for the content of S in lamina at 30 DAS the highest value of 0.292 per cent was recorded by T_{16} (S_3B_3) followed by T_{15} (S_3B_2).The lowest value of 0.122 per cent was recorded by T_2 (S_0B_1) preceded by T_1 (S_0B_0), both of which received no S.

S_3 (30.0 kg S ha^{-1}) was significantly the highest treatment followed by S_2 (15.0 kg S ha^{-1}) and recorded the values of 0.259 and 0.200 per cent respectively. The lowest value of 0.132 per cent was recorded by S_0.Among the levels of B, B_3 (7.5 kg B ha^{-1}) and B_2 (5.0 kg B ha^{-1}) were on par and were significantly superior to the other levels and recorded a value of 0.205 per cent. The lowest values recorded were 0.132 and 0.170 being shown by S_0 (0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}) respectively.

Table 31. S content of plant parts at 30 DAS (%)

Treatments	Lamina	Petiole	Midrib	Internode
S_0 B_0	0.125	0.0460	0.0133	0.0716
S_0 B_1	0.122	0.0789	0.0163	0.0123
S_0 B_2	0.130	0.0890	0.0241	0.0139
S_0 B_3	0.152	0.0416	0.0258	0.0149
S_1 B_0	0.151	0.0693	0.0277	0.01872
S_1 B_1	0.155	0.0642	0.0283	0.0233
S_1 B_2	0.166	0.0792	0.0284	0.0297
S_1 B_3	0.164	0.0772	0.0292	0.0336
S_2 B_0	0.174	0.0884	0.0432	0.0360
S_2 B_1	0.194	0.0971	0.0402	0.0425
S_2 B_2	0.220	0.1090	0.0437	0.0644
S_2 B_3	0.213	0.1040	0.0414	0.0814
S_3 B_0	0.259	0.1030	0.0516	0.0884
S_3 B_1	0.211	0.1230	0.0525	0.1170
S_3 B_2	0.273	0.1510	0.0965	0.1040
S_3 B_3	0.292	0.1590	0.0575	0.1510
S_0	0.132	0.6390	0.0199	0.0120
S_1	0.159	0.0725	0.0284	0.0263
S_2	0.199	0.0996	0.0421	0.0560
S_3	0.259	0.1340	0.0645	0.1152
B_0	0.177	0.0766	0.0339	0.0376
B_1	0.170	0.0905	0.0343	0.0488
B_2	0.197	0.1070	0.0384	0.0530
B_3	0.205	0.0955	0.0482	0.0703
F-S	86.38^{**}	14.38^{**}	6.45^{**}	680.32^{**}
F-B	7.59^{**}	4.31*	2.75^{NS}	60.17**
F-S.B	2.32^{NS}	2.89*	2.65*	12.72**
CD - S	0.0179	0.0250	0.0231	0.00528
CD - B.	0.0179	0.0250	-	0.00528
CD - S.B	-	0.0500	0.0462	0.0106

4.3.1.2.2 Petiole

The treatment combination which recorded the highest value of 0.159 in this case was also T_{16} (S_3B_3) followed by T_{15} (S_3B_2). The lowest value of 0.0416 per cent recorded in this case was that of T_4 (S_0B_3) preceded by T_1 (S_0B_0).

S_3 (30.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) were the levels which recorded the highest S content in petiole and showed values of 0.134 per cent and 0.107 per cent respectively. This was followed by S_2 (15.0 kg S ha^{-1}) and B_3. The lowest values of 0.0639 and 0.0767 per cent were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.3.1.2.3 Midrib

The S content of midrib at 30 DAS was not significantly influenced by the interaction of different levels of S and B. T_{16} (S_3B_3) showed the value of 0.0965 per cent. The lowest value recorded by T_1 (S_0B_0) was 0.0133 per cent.

Different levels of S had a significant effect on this parameter. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 0.0645 per cent and 0.0482 per cent respectively. S applied at the highest level in combination with B at increasing levels recorded higher values. The lowest values recorded 0.0199 per cent and 0.0339 per cent respectively being shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

4.3.1.2.4 Internode

The levels of both S and B and their different combinations were significantly superior in the case of S content in internode. T_{16} (S_3B_3) recorded the significantly highest value of 0.151 per cent followed T_{14} (S_3B_1) and T_{15} (S_3B_2). The lowest value of 0.0716 per cent was recorded by T_1 (S_0B_0).

Among the different levels of S, S_3 (30.0 kg S ha^{-1}) recorded the highest value of 0.115 per cent which was significantly superior to the other three levels. In the case of the levels of B also, B_3 (7.5 kg B ha^{-1}) recorded the significantly highest value of 0.0703 per cent which was 32.64 per cent higher than B_2. The lowest values of 0.0120 per cent and 0.0376 per cent was shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.3.1.3 40 DAS (Table 32)

4.3.1.3.1 Lamina

At 40 DAS, same trend was repeated such that increasing levels of S gradually increased the S content in the plant parts. T_{16} (S_3B_3) recorded the highest value of 0.265 per cent which was on par with T_{15} (S_3B_2). The lowest value of 0.0210 per cent was recorded by T_1 (S_0B_0).

The levels of S and B and their interaction had a significant effect on the S content of lamina. S_3 (30.0 kg S ha^{-1}) recorded the superior value of 0.238 per cent among the levels of S. B_3 (7.5 kg B ha^{-1}) recorded the highest value of 0.168 per cent. The lowest values of 0.0754 per cent and 0.123 per cent were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.3.1.3.2 Petiole

The interaction between different levels of S and B had no significant effect with regard to the S content of petiole at 40 DAS. However, as in the case of other stages, the highest value of 0.151 per cent was shown by T_{16} (S_3B_3) followed by T_{15} (S_3B_2) and the lowest value of 0.0355 per cent by S_0B_0 (T_1).

The levels of both S and B were significant for the S content of petiole. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the superior levels followed by their next higher levels. S_3 (30.0 kg ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the values of 0.141 and 0.114 per cent respectively. S_0 (0 kg S

Table 32. S content of plant parts at 40 DAS (%)

Treatments	Lamina	Petiole	Midrib	Internode
S_0 B_0	0.0211	0.0355	0.0510	0.0460
S_0 B_1	0.0745	0.0380	0.0655	0.0481
S_0 B_2	0.1020	0.0411	0.0704	0.0595
S_0 B_3	0.1040	0.0545	0.0847	0.0699
S_1 B_0	0.1180	0.0465	0.0875	0.0702
S_1 B_1	0.1260	0.0826	0.0909	0.0717
S_1 B_2	0.1340	0.1070	0.1030	0.0819
S_1 B_3	0.1400	0.1180	0.1130	0.0700
S_2 B_0	0.1510	0.1170	0.1360	0.0972
S_2 B_1	0.1610	0.1210	0.1370	0.1040
S_2 B_2	0.1610	0.1270	0.1470	0.1000
S_2 B_3	0.1640	0.1320	0.1540	0.1020
S_3 B_0	0.2020	0.1330	0.1710	0.1110
S_3 B_1	0.2230	0.1380	0.1810	0.1030
S_3 B_2	0.2630	0.1430	0.1830	0.1200
S_3 B_3	0.2650	0.1510	0.1850	0.1580
S_0	0.0754	0.0423	0.0679	0.0559
S_1	0.1290	0.0886	0.0984	0.0735
S_2	0.1590	0.1240	0.1430	0.1010
S_3	0.2380	0.1410	0.1800	0.1230
B_0	0.1230	0.0830	0.1110	0.0812
B_1	0.1460	0.0948	0.1190	0.0816
B_2	0.1650	0.1050	0.1260	0.0906
B_3	0.1680	0.1140	0.1340	0.1000
F-S	595.10**	77.86**	19.34**	130.91**
F-B	55.82**	7.12**	1.74^{NS}	11.81**
F-S.B	9.10**	2.48^{NS}	4.12**	5.45**
CD - S	0.00838	0.0149	0.0338	0.0078
CD - B.	0.00838	0.0149	-	0.0078
CD - S.B	0.0168	-	0.0675	0.0156

ha^{-1}) and B_0 (0.0 kg B ha^{-1}) recorded the lowest values of 0.0423 per cent and 0.0830 per cent respectively.

4.3.1.3.3 Midrib

In the case of midrib, only the levels of S had significant effect upon the referred parameter. The highest value (0.185 per cent) as in the case of other treatment combinations was recorded by T_{16} (S_3B_3) and the lowest of 0.051 per cent by T_1 (S_0B_0) preceded by T_2 (S_0B_1).

S_3 (30.0 kg S ha^{-1}) recorded significantly the highest value of 0.180 per cent followed by S_3. Among the levels of B, B_3 (7.5 kg B ha^{-1}) produced the highest value of 0.134 per cent. The lowest values of 0.0679 per cent and 0.111 per cent were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.3.1.3.4 Internode

It is obvious from the data that the interaction between different levels of S and B had significant influence on the S content of internode. T_{16} (S_3B_3) recorded the highest value followed by T_{15} (S_3B_2) and the lowest value was shown by T_1 (S_0B_0). The values ranged from 0.0460 to 0.158 per cent.

The S content of internode was significantly influenced by the four levels of S and B and their interaction. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were significantly superior to their lower levels and recorded the values of 0.123 per cent and 0.100 per cent respectively. The lowest values of 0.0559 per cent and 0.0812 per cent were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.3.1.4 50 DAS (Table 33)

4.3.1.4.1 Lamina

On critical examination of the data, it had been observed that the interaction effect of the levels of S and B were not significant for the S content. However the highest value of 0.448 per cent was recorded by T_{16} (S_3B_3), the combination treatment which received S and B at the highest level. The lowest value of 0.214 per cent was recorded by T_1 (S_0B_0).

Statistical analysis of the data indicated that application of different levels of S and B had a significant effect on the S content of lamina at 50 DAS. Increasing levels of S and B increased the S content and the highest values in both the case of S and B was recorded with S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) with the values of 0.441 per cent and 0.396 per cent respectively. This was followed by S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}). The lowest values recorded were 0.292 per cent and 0.351 per cent being shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.3.1.4.2 Petiole

The interaction between different levels of S and B had no significant effect on the S content of petiole at 50 DAS. The highest value among the combination treatment was recorded by T_{16} (S_3B_3) and the values ranged from 0.466 per cent to 0.151 per cent (T_1).

Significant effect was observed only with the different levels of S and the highest value of 0.425 per cent was recorded by S_3. Among the B levels B_3 (7.5 kg B ha^{-1}) recorded the highest value of 0.340 per cent. The lowest values of 0.201 and 0.275 per cent was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.3.1.4.3 Midrib

It is explicit from the data that the application of different levels of S and B .and their interaction had significant effect on the S content of midrib. T_{16}(S_3B_3) recorded the significantly superior value of 0.422 per cent followed by T_{15} (1.03%). The lowest value of 0.212 per cent was observed with T_1 (S_0B_0).

Table 33. S content of plant parts at 50 DAS (%)

Treatments	Lamina	Petiole	Midrib	Internode
$S_0 B_0$	0.214	0.151	0.212	0.201
$S_0 B_1$	0.323	0.193	0.230	0.211
$S_0 B_2$	0.324	0.216	0.241	0.241
$S_0 B_3$	0.306	0.245	0.253	0.254
$S_1 B_0$	0.325	0.270	0.273	0.258
$S_1 B_1$	0.341	0.278	0.337	0.263
$S_1 B_2$	0.382	0.296	0.343	0.270
$S_1 B_3$	0.396	0.299	0.347	0.286
$S_2 B_0$	0.407	0.308	0.360	0.312
$S_2 B_1$	0.426	0.308	0.365	0.315
$S_2 B_2$	0.425	0.321	0.369	0.330
$S_2 B_3$	0.434	0.351	0.381	0.345
$S_3 B_0$	0.457	0.373	0.384	0.362
$S_3 B_1$	0.420	0.402	0.394	0.370
$S_3 B_2$	0.439	0.460	0.410	0.380
$S_3 B_3$	0.448	0.466	0.422	0.395
S_0	0.292	0.201	0.234	0.227
S_1	0.361	0.285	0.325	0.269
S_2	0.423	0.322	0.369	0.326
S_3	0.441	0.425	0.403	0.377
B_0	0.351	0.275	0.307	0.283
B_1	0.378	0.295	0.332	0.290
B_2	0.393	0.323	0.341	0.305
B_3	0.396	0.340	0.351	0.320
F-S	29.07**	11.29**	134.55**	60.01**
F-B	5.03*	2.08^{NS}	23.90**	8.57**
F-S.B	2.12^{NS}	2.10^{NS}	11.69**	3.51*
CD - S	0.0845	0.0831	0.108	0.132
CD - B.	0.0845	-	0.108	0.132
CD - S.B	-	-	0.215	0.265

As in the case of the other plant parts, the different levels of S and B and their had a significant effect on the S content of the midrib and the highest values of 0.403 per cent and 0.351 per cent were recorded by S_3 (30.0 kg S ha^{-1}) and B_3. The lowest values of 0.234 per cent and 0.307 per cent was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.3.1.4.4 Internode

Perusal of the data revealed that T_{16} (S_3B_3) was significantly the superior treatment among the different combinations which showed a value of 0.395 per cent and this was followed by the treatment which received S at the highest level of 30 kg ha^{-1}. The lowest value of 0.201 per cent was recorded by T_1 (S_0B_0) preceded by T_3 (0.34%).

The different levels of S and B and their different combinations had a significant effect on the S content of internode. S_3 (30.0 kg S ha^{-1}) recorded the significantly highest value (0.377 per cent) followed by S_2 (0.326 per cent). The lowest value of 0.227 per cent was shown by S_0. Among the B levels, B_3, the significantly highest treatment recorded a value of 0.320 per cent followed by B_2 (0.66per cent). The lowest value recorded was by B_0 as 0.283 per cent.

4.3.2 Boron

The effect of different levels of S and B and the different combination of these nutrients were significant for the B content in plant parts taken at all the sampling stages. The results are presented in Table

4.3.2.1 20 DAS (Table 34)

4.3.2.1.1 Lamina

The interaction of different levels of S and B had significant effect on the B content of lamina as evident from the data. The highest value of 40.44 mg kg^{-1} was shown by T_{16} (S_3B_3) which was on par with T_{15} (S_3B_2). This was followed by T_4 (S_0B_3) and T_{12} (S_2B_3) both of which received B at 7.5 kg ha^{-1}. The lowest value of 17.72 was shown by T_1 (S_0B_0).

Regarding the main effect of different levels of S and B, it had been observed that S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the significantly superior values of 35.51 mg kg^{-1} and 36.27 mg kg^{-1} respectively. This was followed by S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}). The lowest values of 25.15 and 21.27 was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.3.2.1.2 Petiole

The B content of petiole was significantly influenced by the application of different levels of S and B and their interaction with each other. T_{16} (S_3B_3) recorded the significantly superior value (40.05 mg $plant^{-1}$) than all the other combinations and the lowest value of 10.13 mg $plant^{-1}$ was recorded by T_1 (S_0B_0) preceded by T_9 (S_2B_0). All the treatments were significantly superior to T_1 (S_0B_0).

S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the significantly highest value followed by S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}). The values were 34.40 mg $plant^{-1}$ and 33.07 mg $plant^{-1}$ respectively. The lowest values of 22.32 and 22.25 were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.3.2.1.3 Midrib

The highest value of 38.60 mg $plant^{-1}$ was recorded by T_{16} (S_3B_3) followed by T_{12} (31.71 mg $plant^{-1}$), which was on par with T_{15} (30.73 mg $plant^{-1}$) and T_8 (29.55 mg $plant^{-1}$). The lowest value of 14.73 mg $plant^{-1}$ was recorded by T_1 (S_0B_0).

Statistical analysis of the data showed that application of different levels of S and B and their combination had a significant effect on the B content of midrib. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the significantly superior values of 28.35 mg $plant^{-1}$ and 32.01 mg $plant^{-1}$ respectively. The lowest values of 20.57 per cent and 19.50 per cent was shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

Table 34. B content of plant parts at 20 DAS (mg kg^{-1})

Treatments	Lamina	Petiole	Midrib	Internode
$S_0 B_0$	17.72	20.13	14.73	11.11
$S_0 B_1$	22.55	24.38	15.23	12.23
$S_0 B_2$	24.10	26.68	24.13	15.73
$S_0 B_3$	36.23	28.10	28.20	18.63
$S_1 B_0$	18.93	26.05	20.73	16.22
$S_1 B_1$	28.30	28.78	25.63	21.23
$S_1 B_2$	31.10	30.73	28.47	24.41
$S_1 B_3$	33.00	32.00	29.55	28.83
$S_2 B_0$	19.41	24.21	20.51	17.24
$S_2 B_1$	33.12	26.63	21.08	19.14
$S_2 B_2$	32.30	29.62	27.41	28.24
$S_2 B_3$	35.40	32.15	31.71	29.61
$S_3 B_0$	29.01	28.61	22.05	20.32
$S_3 B_1$	35.20	32.20	22.02	24.14
$S_3 B_2$	37.41	36.72	30.73	29.75
$S_3 B_3$	40.44	40.05	38.60	30.01
S_0	25.15	22.32	20.57	14.42
S_1	27.83	29.39	26.09	22.67
S_2	30.06	28.15	25.18	23.56
S_3	35.51	34.40	28.35	26.05
B_0	21.27	22.25	19.50	16.22
B_1	29.79	27.99	20.99	19.18
B_2	31.23	30.94	27.68	24.53
B_3	36.27	33.08	32.01	26.77
F-S	46.28**	195.99**	77.51**	56.59**
F-B	92.82**	175.67**	248.24**	46.79**
F-S.B	4.18**	16.01**	9.28**	38.76**
CD - S	1.950	1.07	1.12	0.197
CD - B.	1.950	1.07	1.12	0.197
CD - S.B	3.899	2.14	2.24	0.394

4.3.2.1.4 Internode

Statistical analysis of the data showed that the interaction between different levels of S and B had significant effect on the B content of internode at 20 DAS. Among the different treatment combinations the values ranged between 11.11 mg plant^{-1} and 30.01 mg plant^{-1} recorded by T_1 (S_0B_0) and T_{16} (S_3B_3) respectively.

The B content of internode was significantly influenced by the application of different levels of S and B and their different combinations. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the significantly superior values of 26.05 mg plant^{-1} and 25.66 mg plant^{-1} respectively. The lowest values of 14.42 per cent and 15.47 per cent was shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

4.3.2.2 **30 DAS (Table 35)**

4.3.2.2.1 Lamina

It can be observed from the data shows that B content in lamina at 30 DAS was significantly influenced by the application of different levels of S and B. Among the treatment combinations of different levels of S and B, the values ranged from 46.52 mg plant $^{-1}$ to 10.72 mg plant^{-1} recorded by T_{16} (S_3B_3) and T_1 (S_0B_0) respectively. T_1 (S_0B_0) was preceded by T_5 (S_1B_0) which also received no B.

It had been observed that the different levels of S and B individually also registered significant effect on the B content of lamina. The highest value of 38.81 mg plant^{-1} and 35.51 mg plant^{-1} among the different levels of S and B was recorded by S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively which were significantly superior to the other levels. The lowest values recorded were 19.20 and 19.67 respectively being shown by S0 and B0 respectively.

Table 35. B content of plant parts at 30 DAS (mg kg^{-1})

Treatments	Lamina	Petiole	Midrib	Internode
$S_0 B_0$	10.72	13.25	13.13	11.03
$S_0 B_1$	16.10	28.10	15.13	14.72
$S_0 B_2$	23.75	31.50	19.12	18.31
$S_0 B_3$	26.25	35.50	25.63	21.08
$S_1 B_0$	13.76	18.27	12.34	14.13
$S_1 B_1$	30.01	36.00	17.63	18.32
$S_1 B_2$	30.61	36.00	23.41	21.58
$S_1 B_3$	33.07	39.00	29.13	22.32
$S_2 B_0$	20.60	22.75	13.61	16.63
$S_2 B_1$	27.82	31.50	21.31	16.28
$S_2 B_2$	28.60	34.75	21.56	19.10
$S_2 B_3$	32.20	35.21	25.30	24.90
$S_3 B_0$	33.60	32.50	15.12	20.08
$S_3 B_1$	34.11	34.00	23.34	22.63
$S_3 B_2$	36.00	35.00	28.13	28.34
$S_3 B_3$	39.52	37.11	31.07	28.33
S_0	19.20	27.09	18.25	16.28
S_1	26.86	32.32	20.63	19.08
S_2	28.30	31.05	20.44	19.23
S_3	35.81	34.65	24.41	24.84
B_0	19.67	21.69	13.55	20.08
B_1	27.91	33.21	19.35	17.98
B_2	30.09	33.50	23.05	21.83
B_3	35.51	36.70	27.78	24.16
F-S	119.06**	61.81**	100.74**	264.95**
F-B	79.20**	267.31**	555.83**	310.03**
F-S.B	4.02**	24.53**	14.12**	10.26**
CD - S	2.23	1.21	0.768	0.664
CD - B.	2.23	1.21	0.768	0.664
CD - S.B	4.46	2.43	1.54	1.33

4.3.2.2.2 Petiole

Perusal of the data revealed that the application of treatments had a significant effect on the B content of petiole. T_8 (S_1B_3) recorded the highest value of 39.00 mg plant^{-1} which was on par with T_{16} (S_3B_3), both of which received the highest level of B (7.5 kg ha^{-1}). The lowest value of 13.25 was shown by T_1 (S_0B_0).

As regard to the individual effects of these nutrients, S_3 (30.0 kg S ha^{-1}) recorded the significantly highest value of 34.65 mg plant^{-1} which was followed by S_1 (32.32 mg plant^{-1}). Among the different levels of B, B_3 (7.5 kg B ha^{-1}) was significantly superior to other levels followed by B_2 (5.0 kg B ha^{-1}) and they recorded the values of 36.70 mg plant^{-1} and 33.50 mg plant^{-1} respectively. The lowest values recorded were 27.09 and 21.69 being shown by S_0 and B_0 respectively.

4.3.2.3 Midrib

The different levels of S and B and their interaction had a significant effect on the B content of midrib at 30 DAS. T_{16} (S_3B_3) was significantly superior to all the treatment combinations. The values ranged from 12.34 mg plant^{-1} T_5 (S_1B_0)) to 31.07 mg plant^{-1}.

S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the significantly superior levels of S and B and recorded the values of 24.41 mg plant^{-1} and 27.78 mg plant^{-1} respectively. They were followed by the next higher levels. S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) recorded the lowest values of 18.25 and 13.55 respectively.

4.3.2.4 Internode

It had been statistically observed that interaction between different levels of S and B registered significant effect on the B content of internode.T_{15} (S_3B_2) recorded the highest value of 28.34 mg plant^{-1} which was on par with T_{16} (S_3B_3). The lowest value of 11.03 mg plant^{-1}was recorded by T_1 (S_0B_0).

The effect of different levels of S and B and their interaction were highly significant for the B content of internode at 30 DAS. The superior level of S and B were S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) which recorded the values of 24.84 mg $plant^{-1}$ and 24.16 mg $plant^{-1}$ respectively. These were significantly superior to their other levels. The lowest values of 16.28 and 17.98 were shown by S0 and B1 respectively.

4.3.3 40 DAS (Table 36)

4.3.3.1 Lamina

It has been statistically observed that application of S and B at different levels and their interaction has a significant effect on the B content of lamina at 40 DAS. T_{16} (S_3B_3) was the significantly superior combination which recorded a value of 45.63. The lowest value of 12.28 was shown by T_{13} (S_3B_0).

Among the S levels, S_1 (7.5 kg S ha^{-1}) recorded the highest value of 36.02 mg $plant^{-1}$ which was significantly higher than the other levels. This was followed by S_3.

B_3 (7.5 kg B ha^{-1}) recorded the highest value (37.29 mg kg^{-1}) among the levels of B and it was followed by B_2 (5.0 kg B ha^{-1}). The lowest values of 21.98 and 19.63 in both the cases were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

4.3.3.2 Petiole

Statistical analysis of the shows that the B content of petiole was significantly influenced by the application of different levels f S and B and their interaction with each other. T_{16} (S_3B_3) recorded the highest value of 39 mg kg^{-1} followed by T_{12} (S_2B_3) and they were on par with each other. The lowest value of 9.75 mg $plant^{-1}$ was recorded by T_1 (S_0B_0) preceded by T_9 (S_2B_0).

With regard to the main effects of different levels of these nutrients, the highest value was recorded by S_3 (34.69 mg $plant^{-1}$) and B_3

Table 36. B content of plant parts at 40 DAS (mg kg^{-1})

Treatments	Lamina	Petiole	Midrib	Internode
$S_0 B_0$	18.10	19.75	11.09	9.29
$S_0 B_1$	18.97	24.50	15.54	12.25
$S_0 B_2$	23.58	33.50	22.5	14.00
$S_0 B_3$	27.28	34.00	29.07	20.60
$S_1 B_0$	22.02	20.75	15.46	11.33
$S_1 B_1$	24.61	26.00	16.13	20.16
$S_1 B_2$	28.33	27.00	24.90	24.07
$S_1 B_3$	30.14	33.00	30.11	25.70
$S_2 B_0$	24.13	23.00	16.58	14.65
$S_2 B_1$	26.81	31.50	18.72	17.23
$S_2 B_2$	28.82	34.75	27.00	21.64
$S_2 B_3$	30.13	37.00	25.23	21.30
$S_3 B_0$	26.28	25.00	18.38	21.49
$S_3 B_1$	29.12	32.00	22.42	23.83
$S_3 B_2$	31.08	36.75	31.49	24.50
$S_3 B_3$	35.63	39.00	33.86	25.96
S_0	21.98	25.44	19.55	14.03
S_1	26.28	26.94	21.65	20.31
S_2	27.47	30.06	21.88	18.70
S_3	30.53	34.69	26.53	23.94
B_0	22.63	19.88	15.38	14.19
B_1	24.88	28.50	18.20	18.36
B_2	27.95	33.00	26.47	21.05
B_3	30.80	35.75	29.57	23.39
F-S	460.03**	45.58**	16.35**	221.08**
F-B	665.52**	131.69**	86.86**	204.09**
F-S.B	117.11*8	11.92**	1.57^{NS}	18.16**
CD - S	0.853	1.82	2.25	0.833
CD - B.	0.853	1.82	2.25	0.833
CD - S.B	1.71	3.65	-	1.67

(35.75 mg plant^{-1}) which were significantly superior to other levels. S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) recorded the lowest values of 25.44 and 19.88 respectively.

4.3.3.3 Midrib

It had been observed tat the B content of midrib was not significantly influenced by the interaction between different levels of S and B. T_{16} (S_3B_3) recorded the highest value of 33.86 mg plant^{-1} which was on par with T_{15} (S_3B_2) and T_8 (S_1B_3). The lowest value of 11.09 mg plant^{-1}was recorded by T_1 (S_0B_0) preceded by T_9 (S_2B_0) and they were on par with each other.

As regard to the individual effects of different levels of S and B, the B content in the midrib at 40 DAS was significantly influenced by the different levels of S and B. The significantly superior values of 26.53 mg plant^{-1} and 29.57 mg plant^{-1} were recorded by S_3 (30.0 kg ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively. S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) recorded the lowest values of 19.55 and 14.87 respectively.

4.3.3.4 Internode

The data analysis shows that T_{16} (S_3B_3) recorded the highest value of 25.96 mg kg^{-1} which was on par with T_8(S_1B_3), both of which received B at 7.5kg ha^{-1}. The lowest value of 9.29 mg kg was registered with the treatment which received no S or B (T_1). All the other treatments recorded significantly higher values compared to T_1 (S_0B_0).

The application of different levels of S and B had significant on the B content of internode at 40DAS. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the significantly highest values of 23.94 mg plant^{-1} and 23.39 mg plant^{-1} respectively. The lowest values of 14.03 and 14.19 was recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

4.3.4 50 DAS (Table 37)

4.3.4.1 Lamina

It is evident from the data that application of different levels of S and B and their interaction with each other has a significant effect upon the content of B in lamina at 50 DAS. The values ranged from 34.04 mg kg^{-1} to 12.25 mg kg^{-1} being recorded by T_{16} (S_3B_3) and T_9 (S_2B_0) respectively. T_{16} (S_3B_3) was followed by T_{15} (S_3B_2) and T_{14}(S_3B_1) all of which were on par among themselves.

The highest value of 28.33 mg kg^{-1} among the different levels of S was shown by S_3 (30.0 kg S ha^{-1}) which was followed by S_0 (0 kg S ha^{-1}) and they were on par with each other. Among the different levels of B, B_3 (7.5 kg B ha^{-1}) recorded the highest value of 28.49 mg kg^{-1} which was on par with B_2 (28.36 mg kg^{-1}). The lowest values of 20.89 and 16.75 was shown by S_1 (7.5 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.3.4.2 Petiole

The interaction effect of S and B were not significant for the B content in petiole. However the highest value of 35.43 mg kg^{-1} was recorded by T_{16} (S_3B_3) followed by T_{15}(S_3B_2) and the lowest value of 22.5 was recorded by T_1.

It is evident from the data shows the significant influence of the levels of S and B on the content of B in petiole. $S_3$and B_3 (7.5 kg B ha^{-1}) recorded the significantly superior values of 31.23 mg kg^{-1} and 30.92 mg kg^{-1} respectively. The lowest values shown were 25.52 (S0) and 24.81(B0).

4.3.4.3 Midrib

Significant influence of different levels of S and B and their interaction on the B content of midrib was observed. The interaction effect of S and B was also significant for the B content and T_{16} (S_3B_3) and T_{12} (S_2B_3) recorded the highest value of 31.5 mg kg^{-1} and were on par with

Table 37. B content of plant parts at 50 DAS (mg kg^{-1})

Treatments	Lamina	Petiole	Midrib	Internode
S_0 B_0	12.25	22.50	11.75	12.31
S_0 B_1	28.02	23.80	12.28	18.47
S_0 B_2	28.59	26.55	13.18	26.13
S_0 B_3	31.07	29.25	21.44	26.05
S_1 B_0	12.44	23.50	12.75	12.91
S_1 B_1	23.50	25.21	27.23	25.31
S_1 B_2	23.50	26.50	29.00	26.73
S_1 B_3	24.10	28.50	29.50	27.08
S_2 B_0	13.05	25.25	26.33	15.41
S_2 B_1	20.89	28.25	26.61	25.63
S_2 B_2	25.78	30.22	28.00	28.15
S_2 B_3	27.25	30.50	31.50	28.31
S_3 B_0	14.29	28.00	21.00	21.75
S_3 B_1	31.91	30.00	24.20	20.42
S_3 B_2	33.11	31.50	26.75	30.50
S_3 B_3	34.04	35.43	31.50	31.61
S_0	24.98	25.52	14.66	20.74
S_1	20.89	25.93	24.62	23.00
S_2	21.74	28.55	28.11	24.38
S_3	28.33	31.23	25.86	26.07
B_0	13.00	24.81	17.96	15.59
B_1	26.08	26.81	23.25	22.45
B_2	27.75	28.69	24.13	27.88
B_3	29.12	30.92	27.92	28.26
F-S	26.02**	9.02**	43.46**	17.38**
F-B	68.51**	8.76**	20.7188	262.09**
F-S.B	19.39**	1.21^{NS}	4.32**	19.69**
CD - S	2.040	2.66	2.72	1.10
CD - B.	2.040	2.66	2.72	1.10
CD - S.B	4.090	-	5.44	2.21

$T_7(S_1B_2)$ and $T_6(S_1B_1)$. The lowest value of 11.75 was recorded by T_1 (S_0B_0) which was on par with T_3 (S_0B_2) and T_5 (S_1B_0).

Among the different levels S_2 (15.0 kg S ha^{-1}) recorded the significant and highest value of 28.11 mg $plant^{-1}$ followed by S_3. Different levels of B had also significant effect upon the B content and the highest value of 27.92 mg $plant^{-1}$ was recorded by B_3 (7.5 kg B ha^{-1}) followed by B_2 (5.0 kg B ha^{-1}). The lowest values of 14.66 and 17.96 was shown by S0 and B_0 (0.0 kg B ha^{-1}) respectively.

4.3.4.4 Internode

It had been statistically verified that the interaction between different levels of S and B registered significant effect on the B content of internode at 50 DAS. $T_{16}(S_3B_3)$ recorded the highest value of 31.61 mg kg^{-1} which was on par with $T_{15}(S_3B_2)$ and the lowest value was shown with T_{13}(12.31 mg kg^{-1}) preceded by T_9 (S_2B_0) and T_1 (S_0B_0) both of which received no B in their treatments.

Among the different levels of S and B, S_1 (7.5 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 25.22 mg kg^{-1} and 28.26 mg kg^{-1} respectively and these were significantly higher than their lower levels. The lowest values of 21.51 and 15.59 was shown by S_0 (0 kg B ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.4 Effect of S and B on the available S content of the soil at different sampling stages (Table 40)

4.4.1 20 DAS

The data on the S content of the soil sampled at 20 DAS are presented in Table. Perusal of the data indicated that the S content of the soil at 20 DAS was significantly influenced by the interaction between different levels of S and B and also by the individual effect of different levels of S. Among the interaction effect, the highest value of 55.25 kg ha^{-1} was recorded by T_{12} (S_2B_3) followed by T_{11}

Table 39. Available S of the soil at different sampling stages (kg ha^{-1})

Treatments	20DAS	30DAS	40DAS	50DAS
$S_0 B_0$	13.94	4.33	15.2	9.73
$S_0 B_1$	11.73	10.58	6.60	14.40
$S_0 B_2$	16.25	14.91	20.50	21.67
$S_0 B_3$	18.13	21.13	22.22	23.17
$S_1 B_0$	36.25	19.46	30.00	25.09
$S_1 B_1$	34.00	35.77	33.50	27.39
$S_1 B_2$	42.50	28.93	37.27	26.50
$S_1 B_3$	22.24	20.73	37.50	28.50
$S_2 B_0$	26.68	41.64	37.00	30.06
$S_2 B_1$	46.25	39.14	32.10	32.50
$S_2 B_2$	48.25	42.02	32.25	32.69
$S_2 B_3$	55.25	16.27	34.25	37.41
$S_3 B_0$	41.64	48.85	38.00	37.38
$S_3 B_1$	32.21	43.50	39.35	38.00
$S_3 B_2$	34.00	29.74	40.16	38.39
$S_3 B_3$	34.00	39.09	45.94	45.44
S_0	15.01	15.72	16.13	17.20
S_1	33.75	26.22	34.57	26.87
S_2	44.11	31.78	33.90	33.17
S_3	35.46	40.294	40.86	39.80
B_0	29.63	30.13	30.05	25.56
B_1	31.05	33.67	27.89	28.07
B_2	35.25	28.90	32.54	29.81
B_3	32.40	21.32	34.98	33.63
F-S	46.68**	6.41**	99.07**	88.75**
F-B	1.788^{NS}	3.42*	8.26 **	11.06**
F-S.B	5.81**	3.60*	3.05 *	1.57^{NS}
CD - S	5.403	12.265	3.219	3.071
CD - B.	-	12.265	3.219	3.071
CD - S.B	10.807	24.531	6.43761	-

(S_2B_2) and were on par with each other. The lowest value of 11.73 kg ha^{-1} was shown by T_2 (S_0B_1) and was on par with T_1 (S_0B_0)

Coming to the main effect of different levels of S and B, S_3 (30.0 kg S ha^{-1}) recorded the highest value of 44.11 and was the significantly superior level. The lowest value of 15.01 kg ha^{-1} was kg ha^{-1} as shown by S_0 (0.0 kg S ha^{-1}). The individual effects of different levels of B were not significant. But the highest value of 35.25 was recorded by B_2 (5.0 kg B ha^{-1}) and was on par with B_3. The lowest value of 29.63 kg ha^{-1} was recorded by B_0 (0.0 kg B ha^{-1}).

4.4.2 30 DAS

A perusal of the data indicated that the S content of the soil was significantly influenced by the interaction of different levels of S and B. It had been observed that the highest value of 48.85 kg ha^{-1} was recorded by T_{13} (S_3B_0) followed by T_{14} (S_3B_1) and T_{11} (S_2B_2) all of which were on par. The lowest value of 4.33 kg ha^{-1} was recorded by T_1 (S_0B_0).

Regarding the individual effects of S and B which were also significant, the highest value of 40.29 kg ha^{-1} was recorded by S_3 (30.0 kg S ha^{-1}) which was on par with S_2. The lowest value of 15.72 kg ha^{-1} was shown by S_0 (0.0 kg S ha^{-1}). Among the individual effect of B, B_1 (2.5 kg B ha^{-1}) recorded the highest value of 33.67 kg ha^{-1} and the lowest value of 21.32 kg ha^{-1} was recorded by B_3 (7.5 kg B ha^{-1}).

4.4.3 40 DAS

It had been observed that the available S content of the soil at 40 DAS was significantly influenced by the interaction between different levels of S and B and their individual effects. The highest value of 45.94 kg ha^{-1} was recorded by T_{16} (S_3B_3) which was on par with T_{15} (S_3B_2). T_2 (S_0B_1) recorded the lowest value of 6.60 kg ha^{-1}.

Among the different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 40.86 kg ha^{-1} and 34.98 kg ha^{-1} respectively.

The lowest values recorded were 16.13 kg ha^{-1} and 27.89 kg ha^{-1} as shown by S_0 (0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}).

4.4.4 50 DAS

It can be inferred that that the interaction between different levels of S and B had no significant effect on the available S content of the soil at 50 DAS. However their main effects were significant. Among the interaction effects, the values ranged between 9.73 kg ha^{-1} and 45.44 kg ha^{-1} recorded by T_1 (S_0B_0) and T_{16} (S_3B_3) respectively.

Among the different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 39.80 kg ha^{-1} and 33.63 kg ha^{-1}. The lowest values recorded were 17.24 kg ha^{-1} and 25.56 kg ha^{-1} recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.5 Effect of S and B on the available B content of the soil at different sampling stages (Table 41)

The data on the available B content of the soil at the four sampling stages are presented in Table 41.

4.5.1 20 DAS

The interaction between different levels of Sand B showed significant effect on the B content of the soil at 20 DAS. The values ranged from 0.208 ppm to 2.19 ppm recorded by T_1 (S_0B_0) and T_8 (S_1B_3). T_8 (S_1B_3) was on par with T_4 (S_0B_3).

Among the different levels of S and B, S_3 (30.0 kg ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 1.60 ppm and 1.94 ppm respectively. The lowest values of 0.978 ppm and 0.816 ppm were recorded by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

4.5.2 30 DAS

Perusal of the data showed that the interaction between different levels of S and B had no significant effect on the available B content at 30 DAS. The

Table 40. Available (Hot Water Extractable) B of soil at the different sampling stages (ppm)

Treatments	20DAS	30DAS	40DAS	50DAS
S_0 B_0	0.208	0.355	0.196	0.161
S_0 B_1	0.511	0.693	0.227	0.560
S_0 B_2	1.060	0.881	0.214	0.577
S_0 B_3	2.140	1.44	0.330	1.350
S_1 B_0	0.566	0.950	0.244	0.761
S_1 B_1	0.713	1.180	0.449	1.26
S_1 B_2	1.540	1.210	0.445	1.370
S_1 B_3	2.190	2.220	0.409	1.570
S_2 B_0	1.150	1.510	0.643	0.870
S_2 B_1	1.050	1.640	0.725	1.210
S_2 B_2	1.530	1.340	0.94	1.760
S_2 B_3	1.610	2.450	1.360	2.030
S_3 B_0	1.340	1.730	0.992	0.795
S_3 B_1	1.470	1.640	1.060	2.260
S_3 B_2	1.800	1.910	1.010	2.110
S_3 B_3	1.810	2.040	1.600	2.140
S_0	0.978	0.841	0.242	0.662
S_1	1.250	1.390	0.387	1.240
S_2	1.330	1.740	0.910	1.470
S_3	1.600	1.830	1.170	1.820
B_0	0.816	1.140	0.519	0.647
B_1	0.934	1.290	0.614	1.320
B_2	1.480	1.330	0.647	1.450
B_3	1.940	2.040	0.925	1.770
F-S	21.87 **	25.60**	75.09**	72.03**
F-B	88.53 **	20.74 **	12.12**	67.92**
F-S.B	9.71**	1.66^{NS}	2.60 *	5.53**
CD - S	0.1658	0.2664	0.1512	0.1731
CD - B.	0.1658	0.2664	0.1512	0.1731
CD - S.B	0.3317	0.5328	0.3023	0.3463

values ranged between 0.355 ppm and 2.45 ppm recorded by $T_1(S_0B_0)$ and $T_{12}(S_2B_3)$ respectively.

The different levels of S and B had significant effect on the parameter and the highest values of 1.83 ppm and 2.04 ppm were recorded by S_3 (30.0 kg S ha^{-1}) and B_3. The lowest values recorded were 0.841 ppm for S_0 (0 kg S ha^{-1}) and 1.14 ppm for B_0 (0.0 kg B ha^{-1}).

4.5.3 40 DAS

The available B content of the soil at 40 DAS are presented in Table. It had been observed that the interaction between different levels of S and B exerted significant influence on the parameter. The values were between 0.196 ppm and 1.60 ppm recorded by T_1 (S_0B_0) and T_{16} (S_3B_3) respectively. T_{16} (S_3B_3) was on par with T_{12} (S_2B_3) and they were significantly superior to the other treatment combinations.

Among the different levels of S and B, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest values of 1.17 ppm and 0.925 ppm and these were significantly superior to the other levels of these nutrients. The lowest values of 0.242 and 0.519 were shown by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}).

4.5.4 50 DAS

The data on the available B content of the soil at 50 DAS are presented in Table. Perusal of the data showed the significant effect of the interaction and main effect of different levels of S and B. With regard to the interaction effect the highest value of 2.26 ppm was shown by T_{14} (S_3B_1) followed by T_{16} (S_3B_3) and were on par with each other. The lowest value recorded was 0.161 by T_1 (S_0B_0).

The individual effects of S and B were also significant with regard to the parameter. The highest values of 1.82 ppm and 1.77 ppm was recorded by S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) respectively. The lowest values recorded were 0.662 ppm and 0.647 ppm by S_0 (0 kg S ha^{-1}) and B_0 (0.0 kg B ha^{-1}) respectively.

DISCUSSION

5. DISCUSSION

The salient results of laboratory and field investigations carried out at College of Agriculture, Vellayani and at Onattukara Regional Agricultural Research Station, Kayamkulam to understand the nutritional roles of S and B in the growth and yield of sesame Variety Thilarani and the standardization of their foliar diagnosis are discussed in this section. The treatments were T_1 (S_0B_0), T_2 ($S_0B_{2.5}$), T_3 ($S_0B_{5.0}$), T_4 ($S_0B_{7.5}$), T_5 ($S_{7.5}B_0$), T_6 ($S_{7.5}B_{2.5}$), T_7 ($S_{7.5}B_{5.0}$), T_8 ($S_{7.5}B_{7.5}$), T_9 ($S_{15}B_0$), T_{10} ($S_{15}B_{2.5}$), T_{11} ($S_{15}B_{5.0}$), T_{12} ($S_{15}B_{7.5}$), T_{13} ($S_{30}B_0$), T_{14} ($S_{30}B_{2.5}$), T_{15} ($S_{30}B_{5.0}$), T_{16} ($S_{30}B_{7.5}$). The different levels of S were S_0 (0 kg S ha^{-1}), S_1 (7.5 kg ha^{-1}), S_2, (15.0 kg S ha^{-1}) and S_3 (30.0 kg S ha^{-1}). The levels of B include B_0 (0.0 kg B ha^{-1}), B_1 (2.5 kg B ha^{-1}), B_2 (5.0 kg B ha^{-1}) and B_3 (7.5 kg B ha^{-1}).

5.1 INCUBATION STUDY

5.1.1 Release pattern of S (Fig.2)

Analysis of the data revealed that the available S content of the soil was significantly influenced by the application of S as gypsum and B as borax through out the period of incubation.

All the treatments showed a gradual increase in the content till 30th DOI and there after a decreasing trend was observed which might be due to the adsorption on the exchange sites or due to microbial immobilisation. The lowest values among all the stages were observed on the 50th DOI.

Increasing levels of S and B showed an increasing trend in the availability of this nutrient. The interaction between S and B at the highest levels of 30 kg ha^{-1} and 7.5 kg ha^{-1} was found to be the most conducive combination for the maximum release of S in the Onattukara sandy soil. At all the four stages of incubation, T_{16} ($S_{30}B_{7.5}$) recorded the highest value and that too on the 30th DOI. This in turn emphasises the favourable

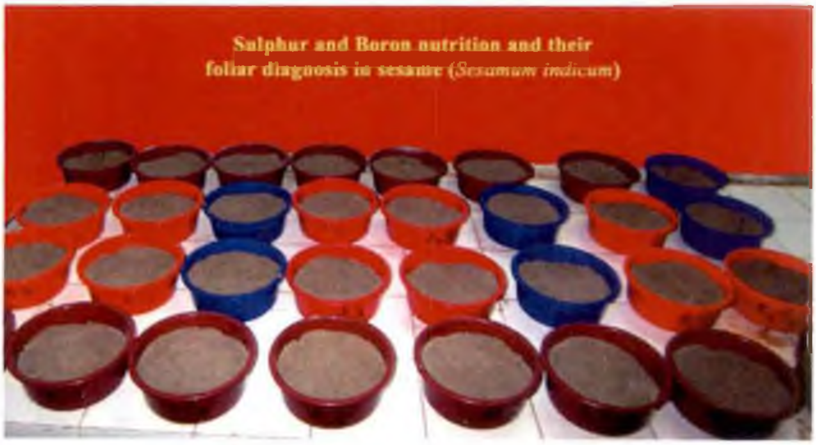

Plate 1. Incubation study

influence of gypsum and borax in the release of soluble S. When the effects of these nutrients are considered individually, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were found to be significantly superior and recorded the highest values at all the stages of incubation.

Beena (2000) reported that by the application of gypsum @ 30 kg S ha^{-1} the available S status of laterite soil considerably increased.

Singh and Mann (2007) reported that the application of S significantly increased the available S status at the harvest stage of groundnut.

Chaurasiya *et al*. (2009) found that increasing the rate of S applied up to 40 kg ha^{-1} increased the available S status of the soil.

These results corroborates the findings of Mathew (2003) such that a gradual increase in the available S status of the soil followed by a decrease during the course of incubation of the laterite soil with phosphogypsum.

5.1.2 Release pattern of B (Fig.2)

The critical examination of the data presented in Table 5 revealed that the available B status of the soil was significantly influenced by the application of different levels of S and B individually and in combination. It had been observed that the treatment which received B at the highest levels registered higher values compared to the lower levels.

As in the case of S, B status of the soil also increased upto the 30^{th} DOI and there after it showed a decreasing trend from the 40^{th} day onwards. The highest rate of application of these nutrients viz. S @30 kg ha^{-1} and B @ 7.5 kg ha^{-1} was found to be the most superior level of these nutrients from the point of view of the release of available B to soil. From the 40^{th} DOI onwards, a gradual decreasing trend was noticed irrespective of the levels applied. By this time, B might have equilibrated in the soil and hence showed a gradual decreasing trend or might have transformed

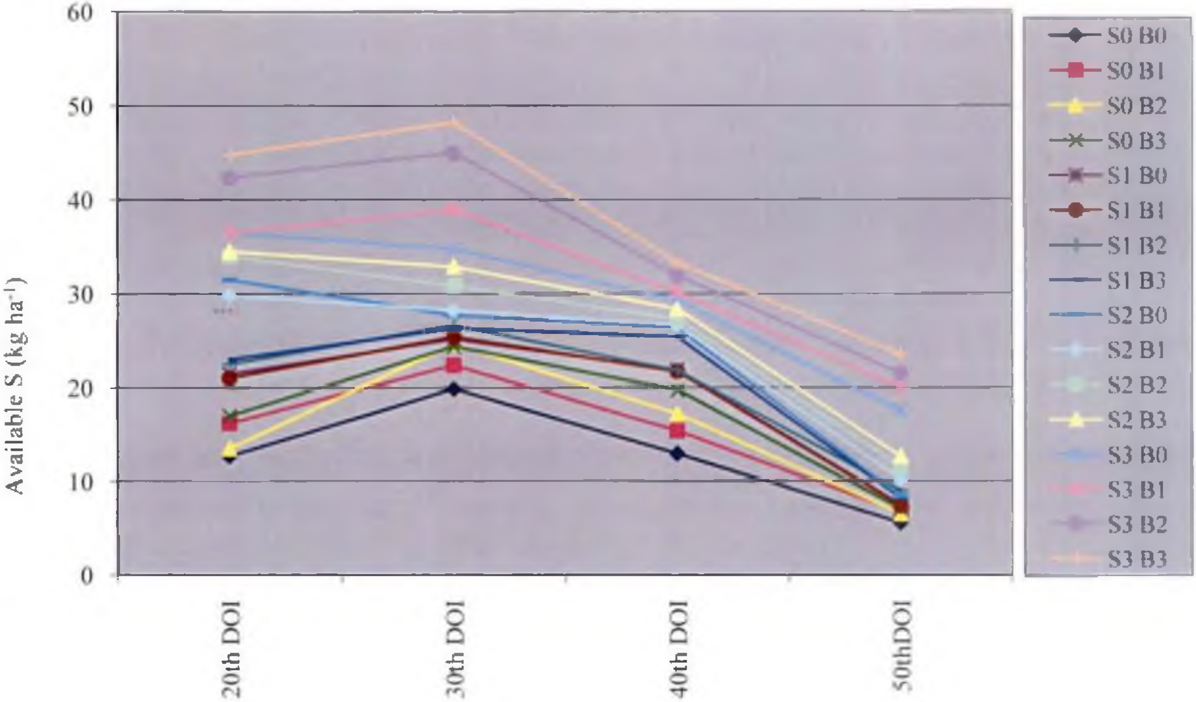

Fig. 2 Available S content at different stages of incubation study (kg ha^{-1})

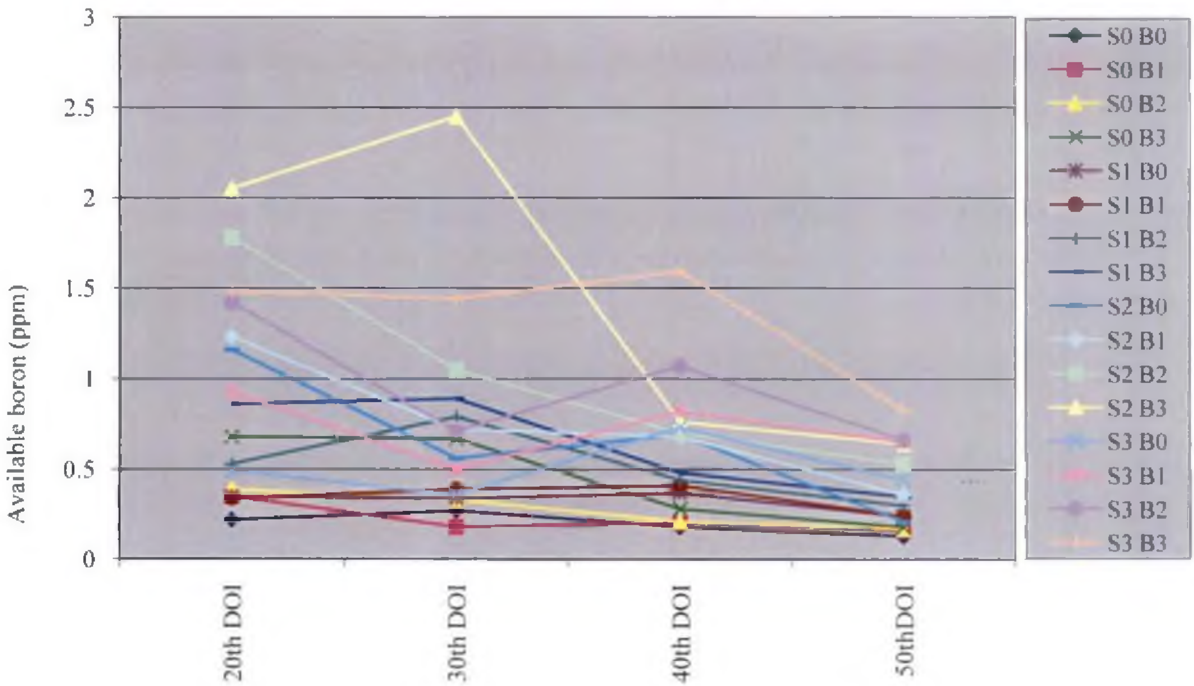

Fig.3 Available B content at different stages of incubation study (ppm)

into non extractable forms. Microbial immobilisation may be yet another reason. The results are in agreement with the findings of Rashid *et al.* (1994) and Raina *et al.* (2006).

5.2 FIELD EXPERIMENT

5.2.1 Effect of S and B on biometric characters of Sesame

The biometric characters of the crop such as height of the plant, number of primary and secondary branches, length of internodes, leaf area, fresh weight of the plant and root characters like root spread and root volume were studied. It had been observed that there was no significant effect due to the application of treatments on the parameters like number of branches plant^{-1} and the root characters like root volume.

The height of the plant was significantly influenced by the application of different levels of S and B and their interaction with each other at all the stages except at 20 DAS. At 30 DAS, the maximum value was shown by T_{10} ($S_{15}B_{2.5}$). At all other stages upto the harvest of the crop the highest value was shown by T_{16} ($S_{30}B_{7.5}$). The treatments could not produce any significant effect at 20 DAS since absorption by the plant might not have occurred because of the scanty root growth.

Regarding the number of primary and secondary branches plant^{-1}, significant effect was recorded upto 30, 40 and 50 DAS and no significant effect was observed at harvest stage. T_9 ($S_{15}B_0$) and T_{16} ($S_{30}B_{7.5}$) recorded the highest values at 30 and 40 DAS. A retardation in the branching habit of the plant as evidenced by the decline in number of primary and secondary branches plant^{-1} after 50 DAS which may be due to crop senescence.

Sulphur and boron have a favourable influence on the production phenology of oil seeds and the interaction between these nutrients enhances the growth characters of sesame. The enhanced chlorophyll synthesis and photosynthesis might have promoted the vegetative growth

Plate 2. General view of the experimental plot

Plate 3. Experimental plot at 50 days after sowing

Plate 4. Experimental plot at 60 days after sowing

of the crop. Both S and B at increasing levels might have led to the increased biomass production at different crop growth stages and it was possibly due to the rapid conversion of synthesized carbohydrates into proteins and thus increased the number and size of cell which caused an increase in plant height and number of branches. The positive influence of S and B in enhancing the growth characters of sesame may be attributed to the better nutritional environment for plant growth at active vegetative growth stages as a result of improvement in root growth, cell multiplication, elongation and cell expansion in the plant body which ultimately resulted in increase in the height. Similar results in sesame were reported earlier by Sarkar and Saha (2005).

Subramaniyan *et al.* (1999) conducted field experiments to study the response of sesame to S application and found significant response with regard to its biometric characters like height and number of branches plant^{-1} by the application of S.

Significant effect of the different levels of S and B and their interaction was observed on the length of internodes only at the 50 DAS and the highest value of 12.08 cm was shown by $T_{16}(S_{30}B_{7.5})$ and the lowest value by $T_2(S_0B_{2.5})$. This in turn shows the positive influence of S on the parameter. Application of S might have enhanced the vegetative growth and promoted the length of internodes in such a way that mutual shading of the leaves will not affect their photosynthetic efficiency to tap the maximum solar energy. This might have later contributed to the improvement in yield attributing characters and enhanced yield.

The fresh weight of the plant was significantly influenced by the application of different levels of S and B till the harvest of the crop. However no significance was observed at the 20DAS.

The direct involvement of S in better absorption of other applied nutrients and cell multiplication as well as cell expansion improved the synthesis of chlorophyll which might have enhanced the photosynthetic efficiency and resulted in higher biomass production.

The leaf area of the plant also showed a positive response towards the application of S and B. An increasing trend with increase in the age of the plant up to 50 DAS was observed. The highest leaf area at 20 and 30 DAS were shown by T_{14} ($S_{30}B_{2.5}$). At 40 and 50 DAS the highest value was shown by T_{16} ($S_{30}B_{7.5}$) which was on par with T_{14} ($S_{30}B_{2.5}$). On critical scrutiny of the individual effects of these nutrients, it was observed that increase in the levels of S showed a positive trend up to 30 kg ha^{-1}. But with regard to the different levels of B, the increasing trend was observed up to 2.5 kg ha^{-1}(B_1) only and there after a decreasing trend was noticed. Increase in the leaf area may be accounted by the enhanced activities of meristematic tissues of the plant which increased the size and number of cells and ultimately increased the total photosynthetic area. This in turn has a positive correlation with the yield of the crop. These findings are in line with those of Sarkar and Saha (2005).

Singh and Singh (1995) reported that S applied @ 30 kg ha^{-1} in soybean significantly increased the leaf area $plant^{-1}$ over control.

Thakur and Patel (2004) also found that S applied @60 kg S ha^{-1} significantly increased the plant height and recorded maximum leaf area index against control in sesame. Similar results were also recorded by Chettri and Mondal (2004) and Dewal and Pareek (2004).

5.2.2 Effect of S and B on root characters

Perusal of the data on the root characters of sesame such as root spread and root volume the influence of the application of different levels of S and B individually and in combination was observed. Among these parameters, only root spread was significantly influenced by the application of different treatments. At the different stages of sampling, root volume did not vary significantly under the influence of the different levels of the nutrients.

But the enhanced root development and proliferation were observed with those treatments which received S and B at the highest levels. But the trend for B was erratic at 50 DAS and at harvest.

The positive influence of S on the root characters of soybean was reported by Zhao *et al.* (2008). Dell and Huang (1997) through their research findings concluded that B plays a primary role in cell enlargement and secondary role in cell division both together contributing to the elongation of roots.

5.2.3 Effect of S and B on yield and yield attributes

5.2.3.1 Days to first and fifty per cent flowering

It can be visualized from the data that the interaction between different levels of S and B had favourable effect in reducing the days to first and fifty per cent flowering. With increase in the level of S, a corresponding decrease in the number of days for the plants to reach the flowering stage was observed. But in the case of B alone, this relationship was observed only upto the application of 2.5 kg ha^{-1}. In the case of B, B_1 (2.5 kg B ha^{-1}) recorded the smallest value which indicates that the increase in B beyond this level has an unfavorable effect by prolonging the crop duration. T_{14} ($S_{30}B_{2.5}$) was found to be the best treatment combination with regard to this parameter. . Application of S and B enhanced the metabolic activities of the plant and thereby might have contributed to the reduction in crop duration.

This observation is of great practical importance for this crop, since its harvesting at proper maturity is very important. Otherwise shattering in the field and consequent yield reduction will result. The reduction in days to flowering is hence a positive observation by the application of S@30 kg ha^{-1} and B@2.5 kg ha^{-1} in Onattukara region. This in turn makes it an ideal catch crop in summer rice fallows of the region between two paddy crops in the cropping sequence.

The number of days to fifty per cent flowering was significantly reduced by the application of S (Krishnamurthi and Mathan, 1996).

5.2.3.2 Seed yield and other yield attributes (Fig.4)

Sulphur and boron registered significant effect on the seed yield of sesame. The positive influence of S was shown at increasing levels. But in the case of B, the increasing trend was shown up to 2.5 kg ha^{-1} and there after showed a decreasing trend. However T_{16} ($S_{30}B_{7.5}$) showed the maximum value.

In the first crop, S_3 was the superior level and produced yield which was 27.12 per cent higher than S_0 among the different levels of S. Among the levels of B, B_1 (2.5 kg B ha^{-1}) was 37.50 per cent higher than B_0.

The same trend was repeated in the case of the second crop also. Among the levels of S, S_3 was the superior level and was 18.69 per cent higher than S_0. In the case of B, an increasing trend was observed upto B_1 and then showed a decreasing pattern. B_3 (7.5 kg B ha^{-1}) showed a marginal increase which may be due to the patches of area having less number of plants noticed in other plots. How ever, B_1 (2.5 kg B ha^{-1}) was 33.52 per cent higher than B_0.B at higher levels promotes germination and hence more number of plants was observed in that plot.

On pooled analysis of the yield data for two years, the same trend was noticed.

The yield attributing characters like number of capsules $plant^{-1}$ and seeds $capsule^{-1}$ were also influenced by the application of different levels of S and B. but the number of seeds $capsule^{-1}$ was not significant. The highest value was recorded by T_{16} ($S_{30}B_{7.5}$) which was on par with T_{14} ($S_{30}B_{2.5}$). S_3 and B_3 showed the highest value among the different levels of S and B.

Regarding the shelling per cent T_7 ($S_{7.5}B_{5.0}$) showed the highest value among the interaction effect, while S_2 and B_1 were the superior

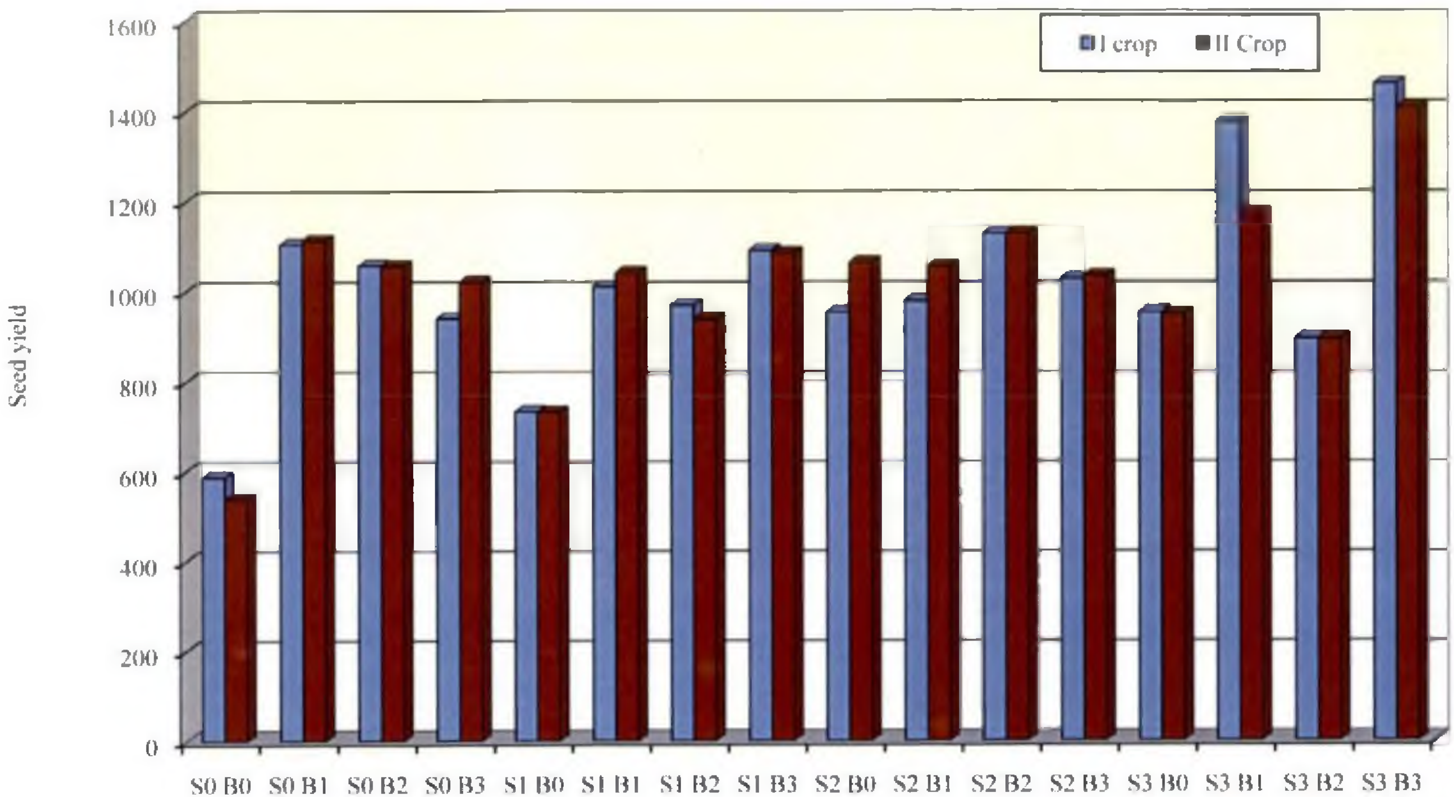

Fig. 4. Seed yield of two crops as affected by the application of treatments (kg ha^{-1})

levels among the different levels of the nutrients. Higher levels of S produced more seed yield but the corresponding pod weight was not that much higher.

In the case of the bhusa yield of the crop, it is evident that the different levels of S and B had a significant effect on the bhusa yield of sesame. T_{14} ($S_{30}B_{2.5}$) produced the highest value and was followed by T_{11} ($S_{15.0}B_{5.0}$). Among the individual effects, S_3 and B_1 were the superior levels. Increasing levels of S showed an increasing trend. But among the levels of B as in the case of the grain yield, there was an initial increase followed by a gradual decrease.

In the case of different levels of S, the increase in seed yield was due to the stimulatory effect on the synthesis of chloroplast and protein which in turn promoted greater photosynthesis ultimately resulting in higher yield over control.

Supply of S might have helped in floral primordial initiation that evidently resulted in greater number of capsules plant^{-1} and seeds capsule^{-1}. More over it helped in increasing the concentration of S in various plant parts to maintain the critical balance of other essential nutrients and resulted in increased metabolic process in the plant. Also the favourable effect of S on the carbohydrate metabolism which led to increased translocation of the photosynthates resulted in the formation of bold seeds.

Sulphur resembles nitrogen and hence improved cell division and elongation and has a favourable influence of the chlorophyll synthesis. S is reported to have a positive effect on yield by virtue of bringing changes in phytochrome balance and the expression of source sink relationship.

Application of S increased pod yield due to early flowering and pod setting. Timely application of S increased the plant growth by increasing the assimilatory surface area. The higher photosynthetic assimilation helped in the net export of carbon to sink and thus increased the number of seed capsule^{-1}. In the case of B, since it increases the pollen producing capacity of anther higher number of seeds capsule was observed. With the increase in the supply of S and B, the process of tissue differentiation from somatic to reproductive and meristematic activity and floral primordial might have increased resulting in more flowers and hence more seed setting. S application plays a vital role in the synthesis of chlorophyll, a part of active centre of some enzymes and affects various metabolic processes which ultimately helped in the growth and development of the plants. The increase in grain yield is largely a function of improvement in yield attributes.

In the case of B, carbohydrate metabolism might had been stimulated which favored the increase in seed yield. Improvement in leaf area might also be responsible for the observed parallel increase in various yield characters. This might have promoted efficient carbon utilization by the plants which enabled them to produce large quantities of photosynthates. B has a positive effect on the photosynthesis performance of plants by influencing phosphorylation processes, reducing the quantity of assimilates consumed by respiration to obtain energy and accelerating the removal of products of photosynthesis. This sustained increase in yield attributes itself culminated in the maximization of seed yield. These results are in agreement with the findings of Sarkar and Saha (2005).

Saren *et al.* (2004) found that the grain and bhusa yield of sesame increased due to increasing levels of S which they ascribed to the uniform distribution of S in the rhizosphere. The positive influence of S and B in improving the yield and yield attributes of sunflower was reported earlier by Shekawat and Shivay (2008).

Critical evaluation of the data on the harvest index of the crop showed that the highest value among the different levels of the nutrients was shown by S_3 (30.0 kg S ha^{-1}) and B_1 (2.5 kg B ha^{-1}). Trend was the same as in the case of the grain yield. Hence we can infer this as the most favourable combination for obtaining maximum yield and yield attributing characters of sesame.

The improved nutritional management as a result of the increased supply of S and B might have favaourably influenced the carbohydrate metabolism and this favourable effect led to the increased transformation of photosynthates towards yield and yield attributing characters. These results corroborates the findings of Saren *et al.* (2004) and Shekawat and Shivay, 2008).

5.2.4 Effect of S and B on dry matter production

It can be observed from the table that the dry matter production was maximum for T_{14} ($S_{30}B_{2.5}$) and with increasing level of S showed an increasing trend for this parameter. No significant difference was observed between B_1, B_2 and B_3 and hence we can infer that B_1 (2.5 kg B ha^{-1}) in combination with S_3 (30.0 kg S ha^{-1}) is favourable for the enhanced dry matter production of sesame.

S and B enhances cell multiplication, elongation and expansion and imparts a deep green colour to leaves due to chlorophyll synthesis resulting in increased dry matter production.

5.2.5 Effect of S and B on the quality parameters of sesame

5.2.5.1 Oil content

Statistical analysis of the data on oil content showed that T_{16} ($S_{30}B_{7.5}$) registered the highest value of 59.45 per cent followed by T_{14}($S_{30}B_{2.5}$) and T_{13} (S_3B_0). This shows the positive influence of increasing levels of S and B on the parameter. Expectedly S_3 and B_3 are the superior levels and hence both S and B have significant influence on the oil content of sesame.

Sulphur is a constituent of glutathione, a compound that plays a vital role in oil synthesis. This positive influence of S on oil synthesis may be attributed to the increased levels of S containing enzymes which are involved in the synthesis of fatty acids. Significant increase in the seed yield may also contribute to the increase in oil content. S is involved in the electron transport chain and enhancement of glucoside formation and is a constituent of multienzyme complex. Increase in concentration of S in soil solution might have resulted in greater absorption of the nutrient and favored the synthesis of several coenzymes like CoA, lipoic acid etc and hence resulted in increase in oil content.

Baphulkar *et al.* (2000) conducted field trials to study the effect of S on yield and quality of safflower and concluded that around 21 per cent increase in oil content over control was obtained by the application of 60 kg S ha^{-1}.

Thorat *et al.* (2005) also reported the significant influence of S in improving the oil content of sesame. Gaina and Silli (1973) proposed an indirect effect of B on the synthesis of fat.

5.2.5.2 Grain protein content

The protein content of the grain was significantly influenced by the application of different levels of S and B. Among the interaction between these nutrients T_{16} ($S_{30}B_{7.5}$) recorded the highest value of 17.50 per cent. Considering the individual effects, S_3 (30.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) showed the highest value.

Sulphur is an integral part of amino acids such as cystene, cystine and methionine. Fifty to eighty per cent of the total S in oil seeds goes to the synthesis of these amino acids. It also act as an activity promoter of various enzymes and vitamins and makes impact on the development processes (Karthikeyan and Shukla, 2008). B stimulates the activity of RNA synthetase and reduced the activity of RNAase and thereby contributes to protein synthesis. B is known to influence the nucleic acid and protein metabolism, cell development and differentiation, membrane permeability and transport of substances. B activates nucleic acid synthesis and optimal transfer of genetic information.

5.2.5.3 Oil constants

The oil constants studied include acid value, iodine value and saponification value. Acid value is defined as the number of milligrams of potassium hydroxide required to neutralize 1g fat or oil and is a measure of the free fatty acid present in the compound. Saponification value may be defined as the number of milligrams of potassium hydroxide required to saponify 1g fat or oil. It is a measure of the average molecular weight of the fatty acid present in the compound and signifies the chain length. The long chain fatty acids found in fats have low saponification value because they have a relatively fewer number of carboxylic functional groups per unit mass of the fat as compared to short chain fatty acids. Iodine value is the mass of iodine consumed by 100g of fat or oil. It indicates the extent of unsaturation of the compound.

It has been observed that both S and B could register significant effect on these parameters. With regard to the acid value, increasing levels of S and B showed a decreasing trend for the parameter which is a favourable aspect to enhance the quality of sesame oil. The treatment which received no S and B showed the highest value (2.99) and the lowest value of 2.00 was observed for T_{16} ($S_{30}B_{7.5}$) preceded by T_{15} ($S_{30}B_{5.0}$) and T_{14} ($S_{30}B_{2.5}$).

Saponification value signifies the chain length of fatty acids. The lowest values among the different levels of S and B were recorded by S_3 and B_2. T_{16} ($S_{30}B_{7.5}$) recorded the lowest value among the interaction treatments and the highest value was shown by T_1 (S_0B_0).

Iodine value indicates the extent of unsaturation of fatty acids. The iodine value was also significantly influenced by the application of the treatments. The positive influence of increasing levels of S and B on this parameter was observed. S_3 and B_1 registered the highest values which were 11.59 per cent and 6.19 per cent higher than S_0 and B_0 respectively. Thus the application of S and B has a definite influence in improving the oil quality. Among the interaction effects, the highest value of 125 was shown by T_{14} ($S_3B_{2.5}$).

Rani *et al.* (2006) also observed that S provides sufficient time for poly unsaturating system which is reflected in higher iodine value. B increased the iodine value and decreased the saponification and acid value which indicates the formation of high molecular weight fatty acids. It also emphasises the role of S in the synthesis of fatty acids, higher proportion of unsaturated ones compared to that of the saturated fatty acids. It also reduced the rancidity of oil.

Ravi *et al.* (2008) found that the application of 30 kg S ha^{-1} resulted in higher proportion of unsaturated fatty acids and reduced the rancidity of the oil by decreasing the acid value.

***5.2.5.4 Fractionation of oil* (Fig.5 and Appendix 2-16)**

Application of S and B recorded desirable effect on reducing the content of undesirable saturated fatty acids such as palmatic acid and stearic acid and also increasing the content of unsaturated fatty acids such as oleic acid and linoleic acid. This indeed is a very favourable observation considering human health. It had been found that the content of these saturated fatty acids decreased with increasing levels of S and B whereas the application of these nutrients had a positive effect on increasing the content of unsaturated fatty acids such as oleic and linoleic acid. B application inhibited the incorporation of acetate into lipids which in turn increased the ratio between unsaturated and saturated fatty acids. Similar observations were recorded by Shekawat and Shivay (2008) in sunflower. Increase in the content of unsaturated fatty acids such as linoleic acid which is an essential fatty acid is indeed a welcome observation with regard to human consumption.

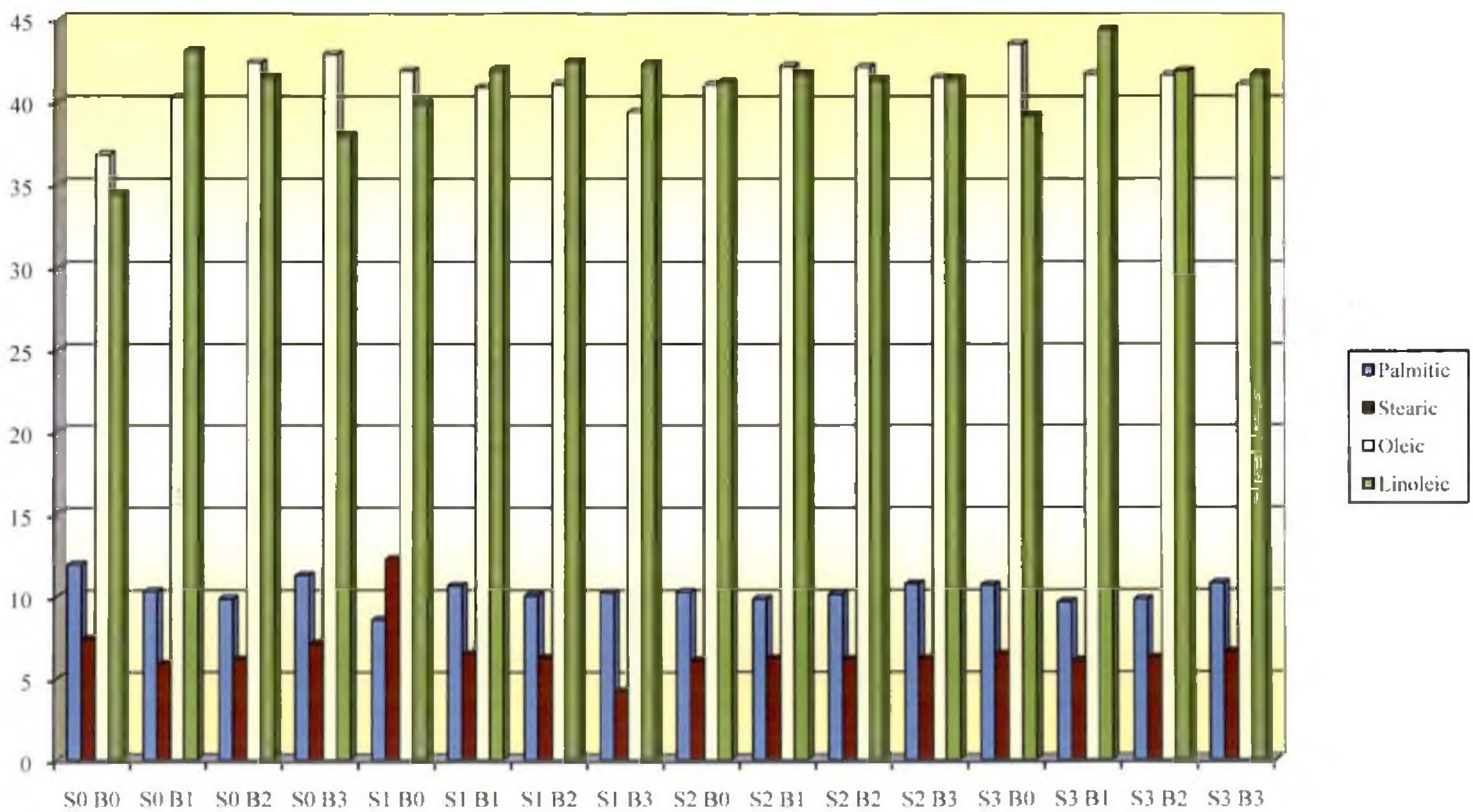

Fig. 5. Fatty acid composition of sesame oil (%)

5.2.6 Effect of S and B on the concentration and uptake of nutrients (Fig. 6 to 17)

The critical examination of the data revealed that the nutrient concentration and uptake were significantly influenced by the application of different levels of S and B.

With regard to the N content, S_3 and B_1 were the significantly superior levels. Increasing levels of S had a synergistic effect on the N content and uptake by both bhusa and grain. T_{16} ($S_{30}B_{7.5}$) recorded the highest value which was on par with T_{15} ($S_{30}B_{5.0}$) and T_{14} ($S_{30}B_{2.5}$). This clearly shows that S along with B at the first level is the most favourable combination as regard to the N content. The same trend was repeated in the second crop also. The total uptake of N also showed the same trend as that of the concentration in plant parts. The high concentration and dry matter production naturally increased the uptake also. Agarwal and Misra (1994) found that N content increased with increasing levels of S and the maximum was observed at 30 kg ha^{-1}.

In the case of P content of bhusa, S_2 (15.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the superior levels and among the interaction effects, T_{12} ($S_{15}B_{7.5}$) recorded the highest value. In the case of grain, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the superior levels and T_{16} ($S_{30}B_{7.5}$) recorded the highest value.

With regard to the total uptake of P, S_2 and B_3 were the superior levels and T_{12} ($S_{15}B_{7.5}$) recorded the highest value among the combination treatments. Synergistic relation between P and S at lower levels of B was observed. The increased uptake and concentration of P with applied S may be due to the increase in availability of P in the soil since both these nutrients are absorbed as anions. If one nutrient is available in higher amount, the available pool of the other also increased.

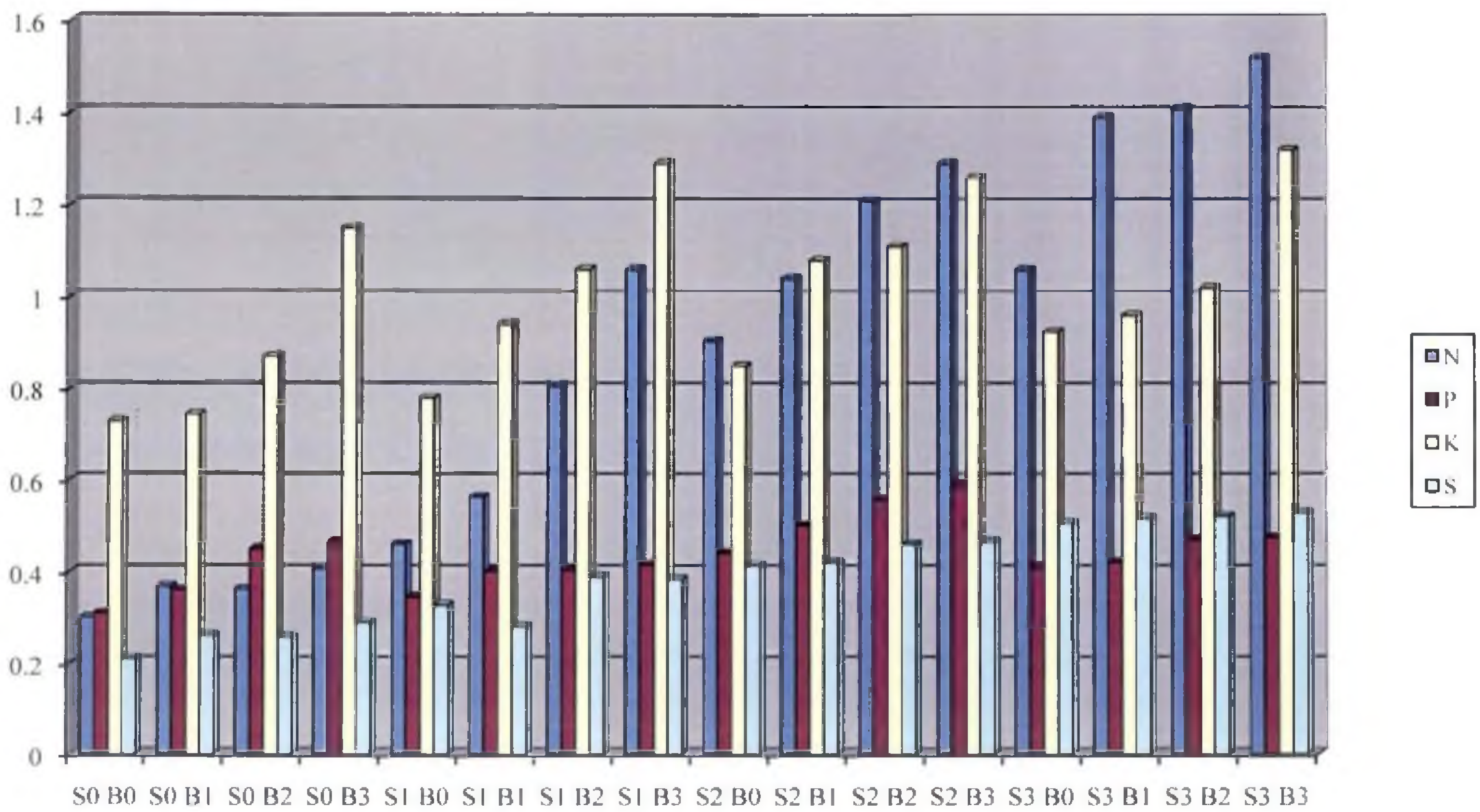

Fig. 6. Concentration of N, P, K and S in bhusa at harvest of the first crop (%)

Shekawat *et al.* (2006) found that increase in the content of P was due to the displacement of phosphate by sulphate from the highly soluble gypsum. Rana *et al.* (2007) concluded that the uptake of P depend on the levels of applied S.

Pandian and Annadurai (2005) conducted an investigation to understand the interaction effect of P and S on sesame in a Typic Ustochrept soil and found positive response with regard to S applied @ 40 kg ha^{-1} in combination with P @ 100 kg ha^{-1}.

Regarding the K content of bhusa, significant effect of the interaction between different levels of S and B and their individual effects were observed. S_2 and B_3 recorded the highest values among their different levels. T_{16} (S_1B_2) showed the highest value among the combination treatments. The Ca from gypsum might have displaced the K from exchange sites. For the grain concentration, S_3 and B_2 were the superior levels and T_{16} ($S_{30}B_{7.5}$) showed the highest value of 0.545 per cent. The uptake also showed the same trend as that of the concentration in plant parts.

The positive interaction of B with the uptake of N, P, and K was reported by Rajkumar and Veeraraghavaiah (2002).

It is evident from the data that the Ca content of the crop was significantly influenced by the application of different levels of S and B. T_{13} ($S_{30}B_0$) recorded the highest value followed by T_{10} ($S_{15.0}B_{2.5}$) which clearly indicated that B has an antagonistic effect on the Ca content of the plant. S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) were the superior levels. As the levels of B increased the content showed a gradual decreasing trend. In the case of grain also the same trend was repeated. This trend was repeated in the uptake also. Janaki *et al.* (2004) reported that increase in B levels showed a negative relationship with Ca content and uptake due to the antagonistic effect between the two nutrients. Both of these are

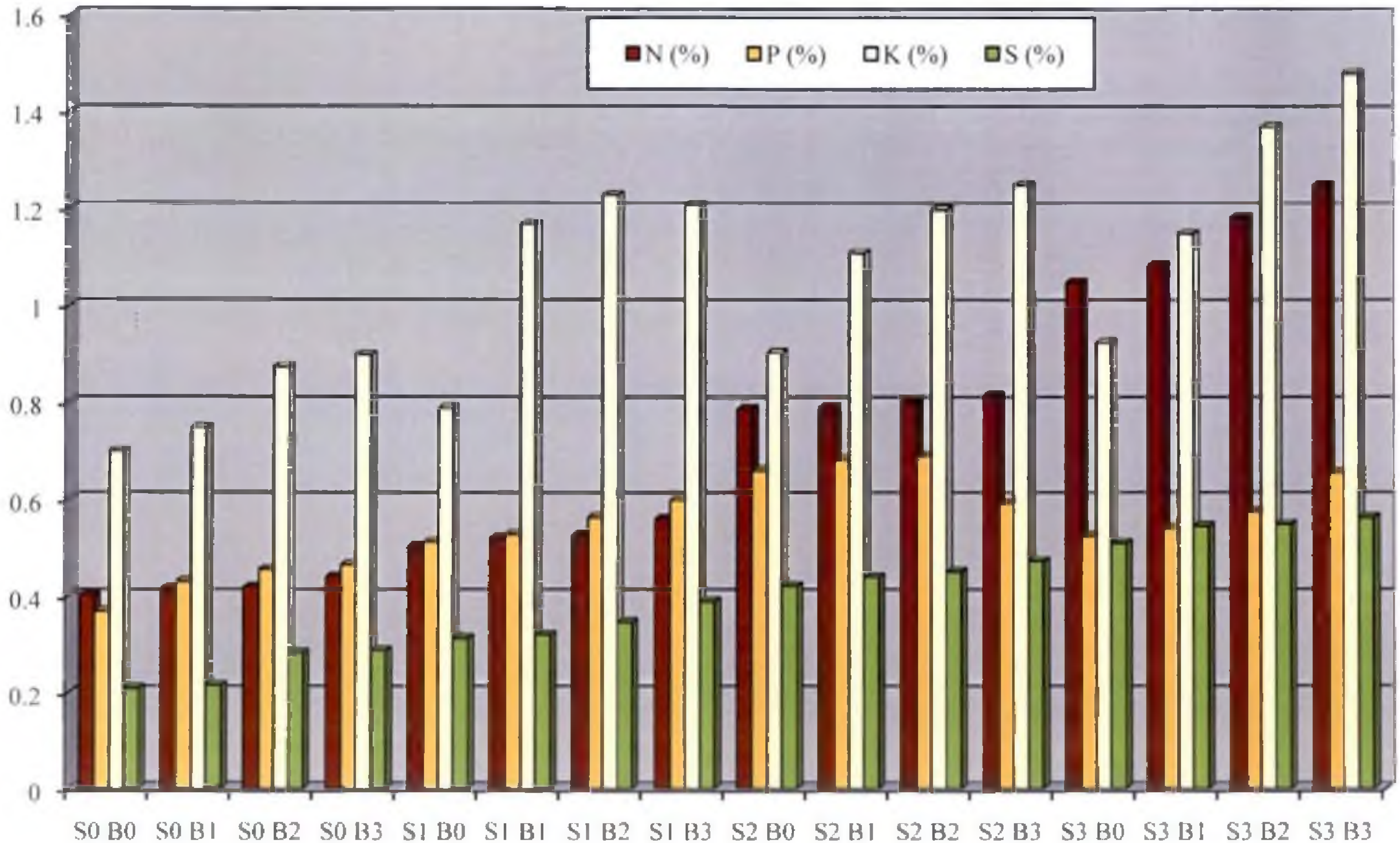

Fig. 7. Concentration of N, P, K and S in bhusa at harvest of the second crop (%)

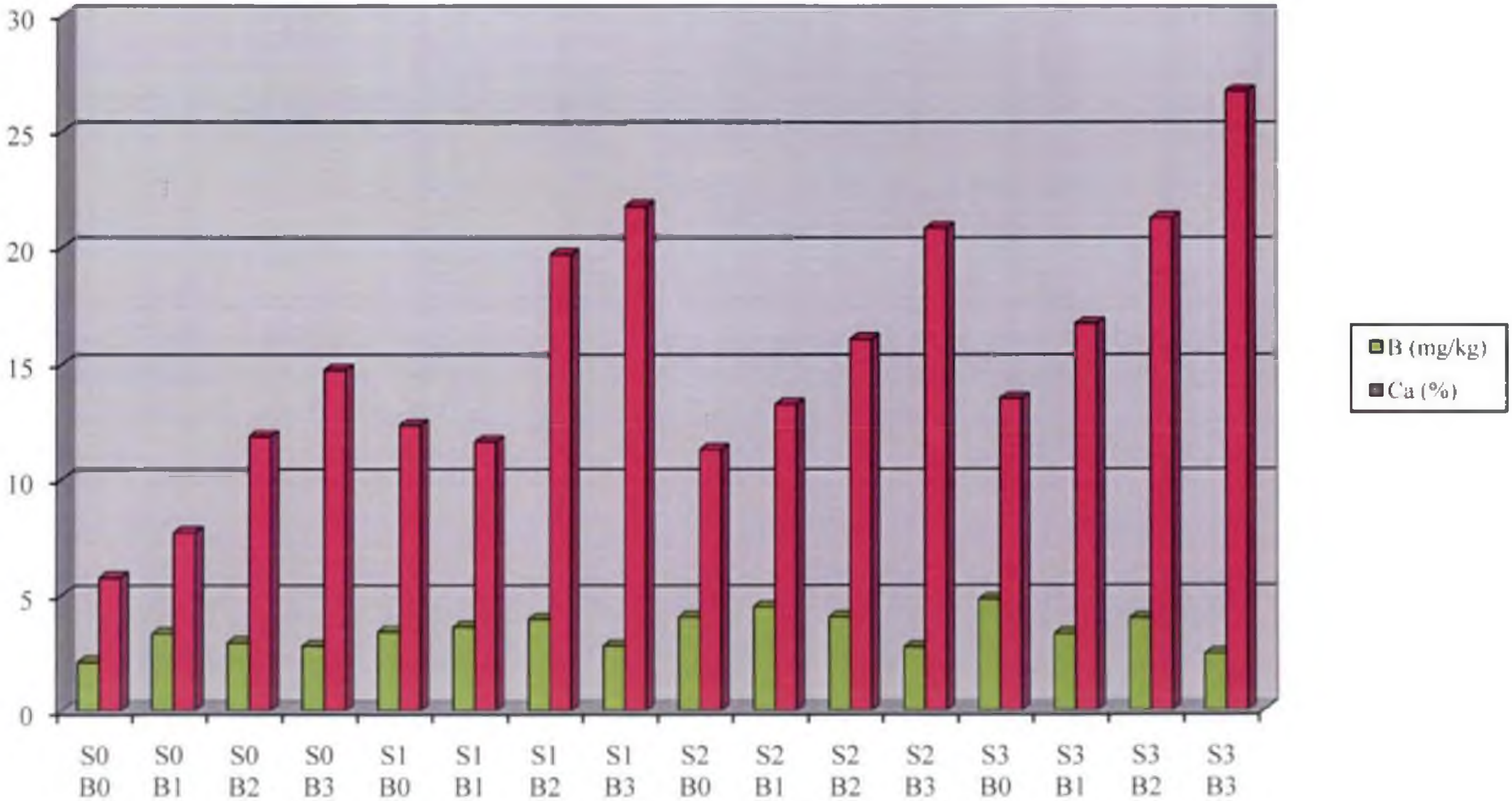

Fig. 8. Concentration of Ca and B in bhusa at harvest of the first crop

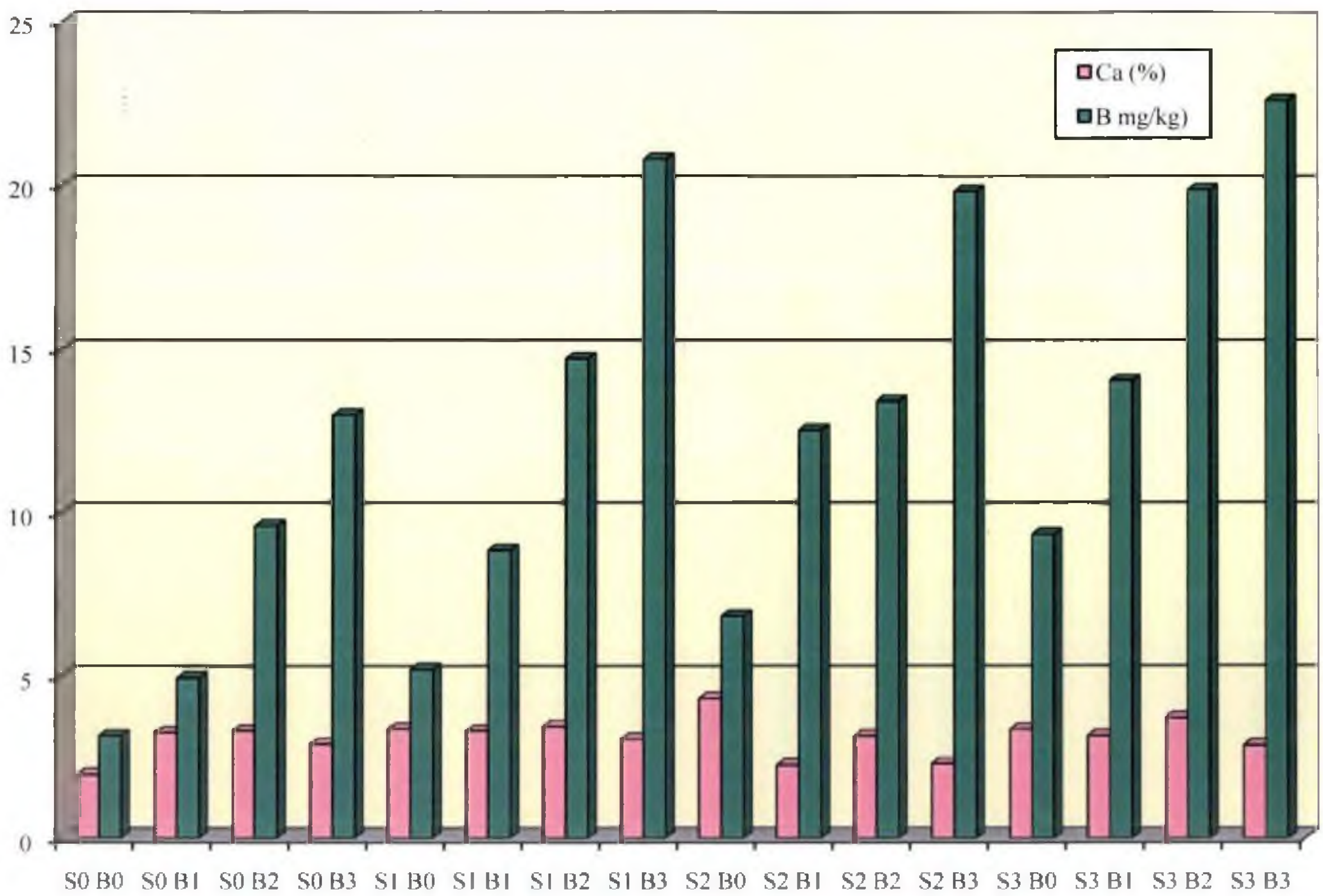

Fig. 9. Concentration of Ca and B of bhusa at harvest of the second crop

immobile in plants. This trend was reported earlier by Patel and Golkiya (1986).

According to Raja *et al.* (2007 b) the maximum N, K, and S uptake in sesame was obtained with 60 kg S ha^{-1} because increased S uptake accelerated increased N utilization.

In the case of Mg content in bhusa, $T_{14}(S_{30}B_{2.5})$ showed the highest value in both the crops which may be due to the positive influence of gypsum containing Ca. S_3 (30.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) recorded the highest values due to the displacement of Mg by Ca from the exchange sites. No significant effect was registered with regard to the Mg concentration in grain. In the case of uptake also, the trend was same.

With regard to the S content, a definite synergistic influence of the two nutrients was observed such that S_3 and B_3 recorded the superior values. Increase in the available S content due to the release of soluble sulphate from gypsum favored the enhanced concentration in bhusa. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the superior levels in the case of grain and T_{16} $(S_{30}B_{7.5})$ recorded the highest value among the interaction effects. A linear increase in concentration was observed with increase in level of applied S. As in the case of concentration in bhusa, the uptake also showed an increasing trend with increasing levels of S and B.

Prasad and Jhangra (2007) found that S removal in sesame is 15.8 kg $tonne^{-1}$. Increase in the uptake was due the combined effect of increase in yield, dry matter production and nutrient concentration.

The synergistic effect of S in the uptake of N, P, K and S in soybean upto 40 kg S $ha^{-1}$was reported by Chaurasiya *et al.* (2009). The crop removal of S had been found to be 11.7 kg $tonne^{-1}$ in sesame (Hegde and Babu, 2009).

In the case of B, as the level of B applied increased, its content in bhusa also showed a gradual increasing trend. A synergistic relation

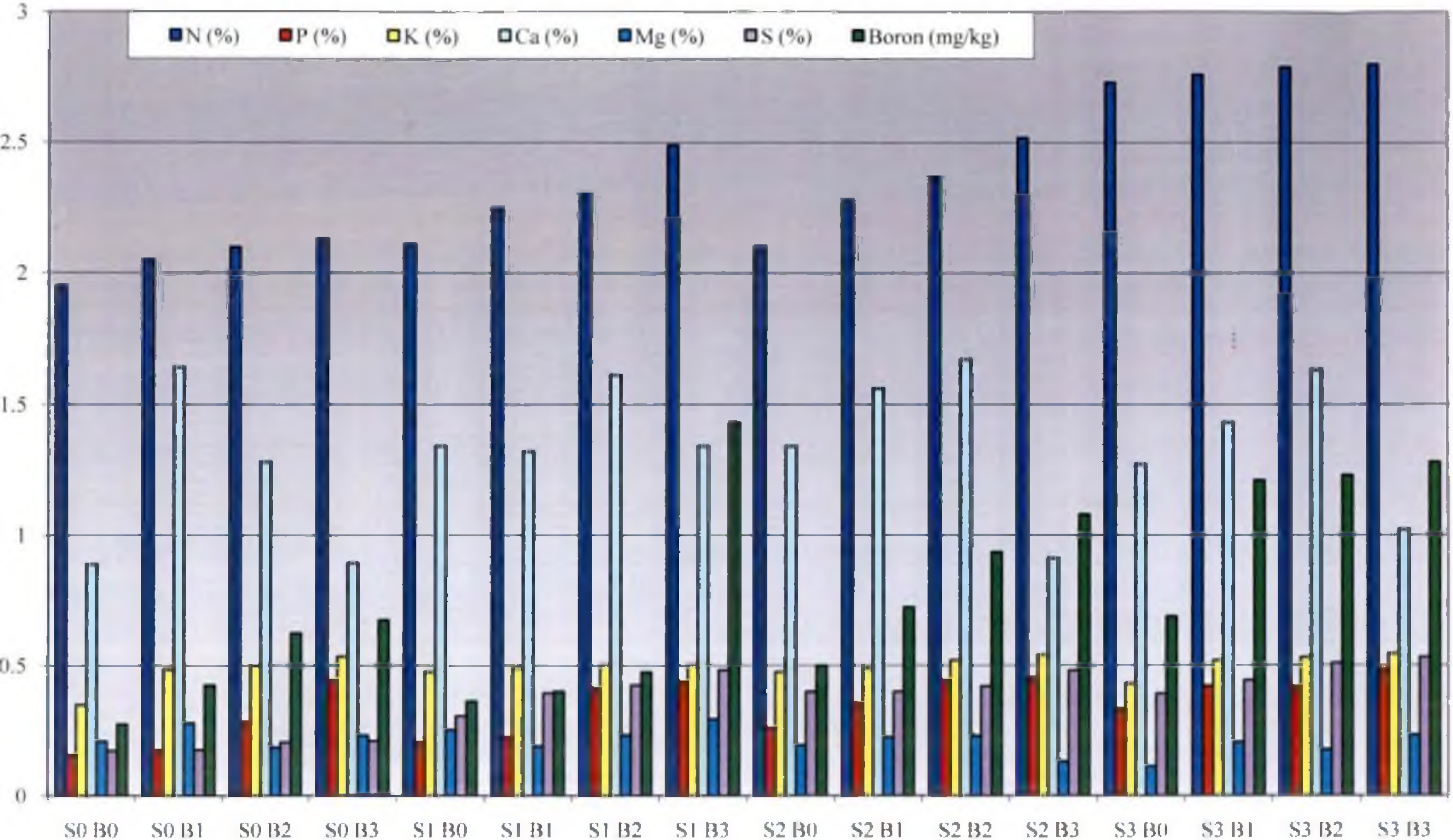

Fig. 10. Nutrient concentration of grain at harvest of the first crop

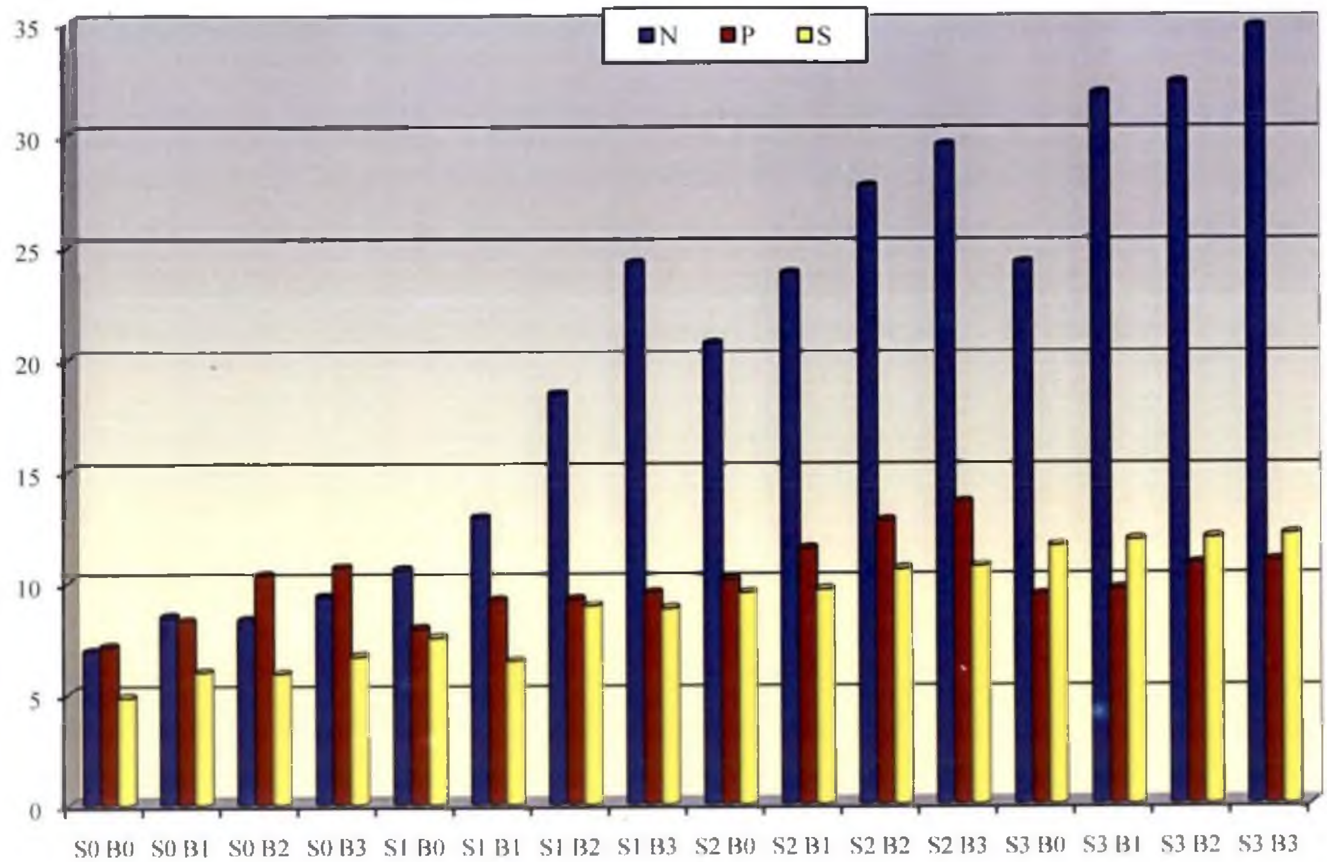

Fig. 11. Nutrient uptake by bhusa at harvest of the first crop (kg ha^{-1})

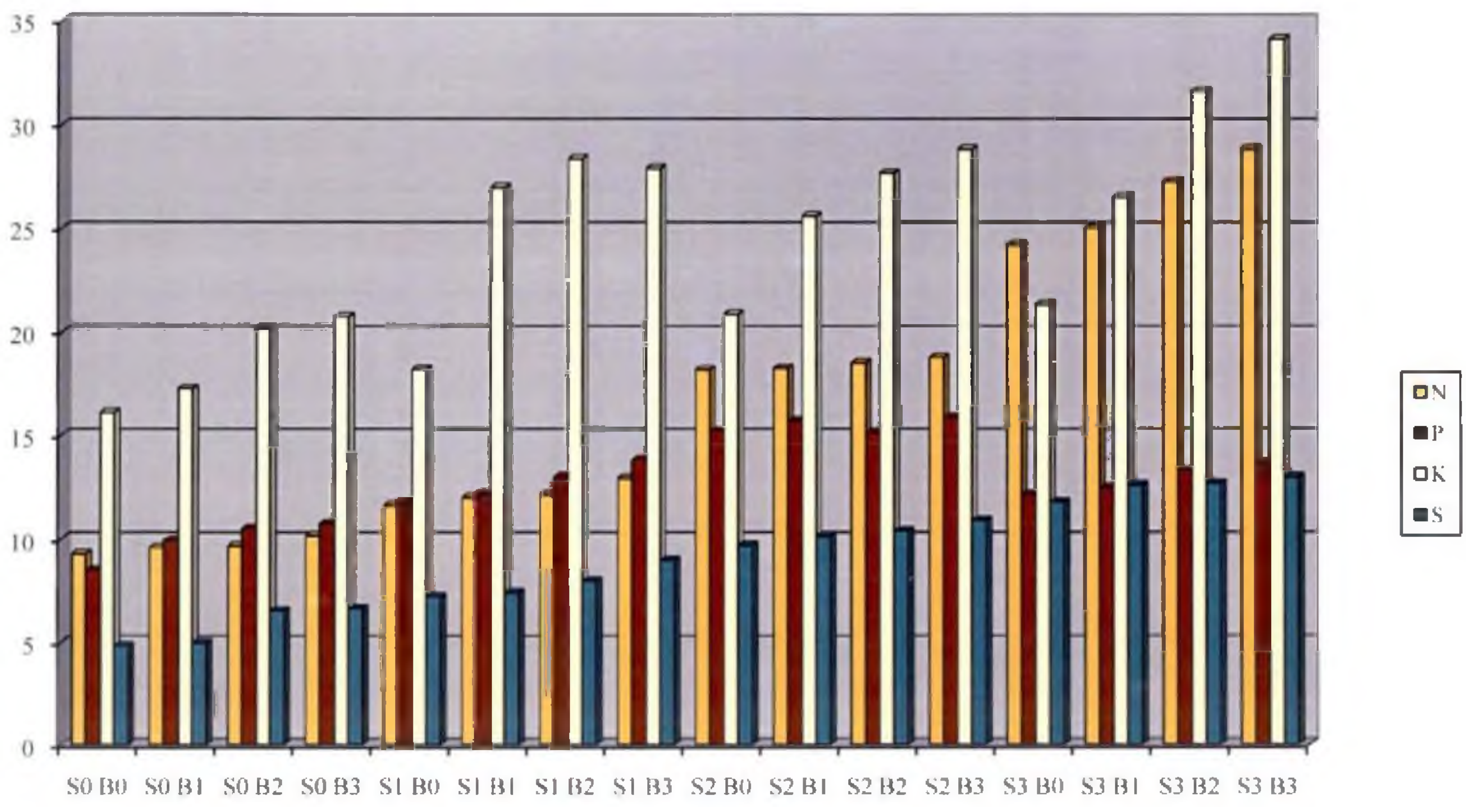

Fig. 12. Nutrient uptake by bhusa at harvest of the second crop (kg ha^{-1})

between the two nutrients was depicted such that S_3 and B_3 were the superior levels. T_{16} ($S_{30}B_{7.5}$) recorded the highest value. The concentration of B in grain was lower than that of bhusa since B is an immobile nutrient. S_2 and B_2 were the superior levels with regard to the total uptake of B and T_{16} (S_3B_3) showed the highest value.

In the case of the concentration of Fe, a positive influence of the different levels of S and B was observed and an increasing trend was noticed for the nutrient. Regarding the content of Mn, S_2 and B_1 (2.5 kg B ha^{-1}) showed the significantly higher values and the trend was same for the grain also. The positive influence of S and B was also reflected in the Cu content and T_{16} ($S_{30}B_{7.5}$) recorded the highest value.

In the case of Zn, S_2 and B_3 were the significantly superior levels for both the crops where as T_9 and T_{16} ($S_{30}B_{7.5}$) registered the highest values among the interaction effects.

The uptake of micronutrients was significantly influenced by the application of different levels of S and B. In the case of Fe and Cu, T_{16} ($S_{30}B_{7.5}$) recorded the highest value showing the positive influence of increasing levels of S and B. For Mn and Zn, T_{11} and T_{12} recorded the highest values which indicates the favourable effect of S @ 15 kg ha^{-1}.

Sasode (2006) reported positive interaction between N, P, K, S and Zn with the S content of plant. The positive effect of B on the uptake of all the nutrients except that of Ca may be due to the improved root growth promoted by it which enhanced the uptake of nutrients.

Shirpurkar *et al.* (2006) observed positive interaction between B and Fe, Mn and Zn. The increased photosynthesis due to the application of S and B enhanced the dry matter production and resulted in the uptake of nutrients. If a plant nutrient is involved in improving the vegetative growth it would certainly improve the uptake of all the nutrients which are required to maintain the growth. Since the application of S and B helped

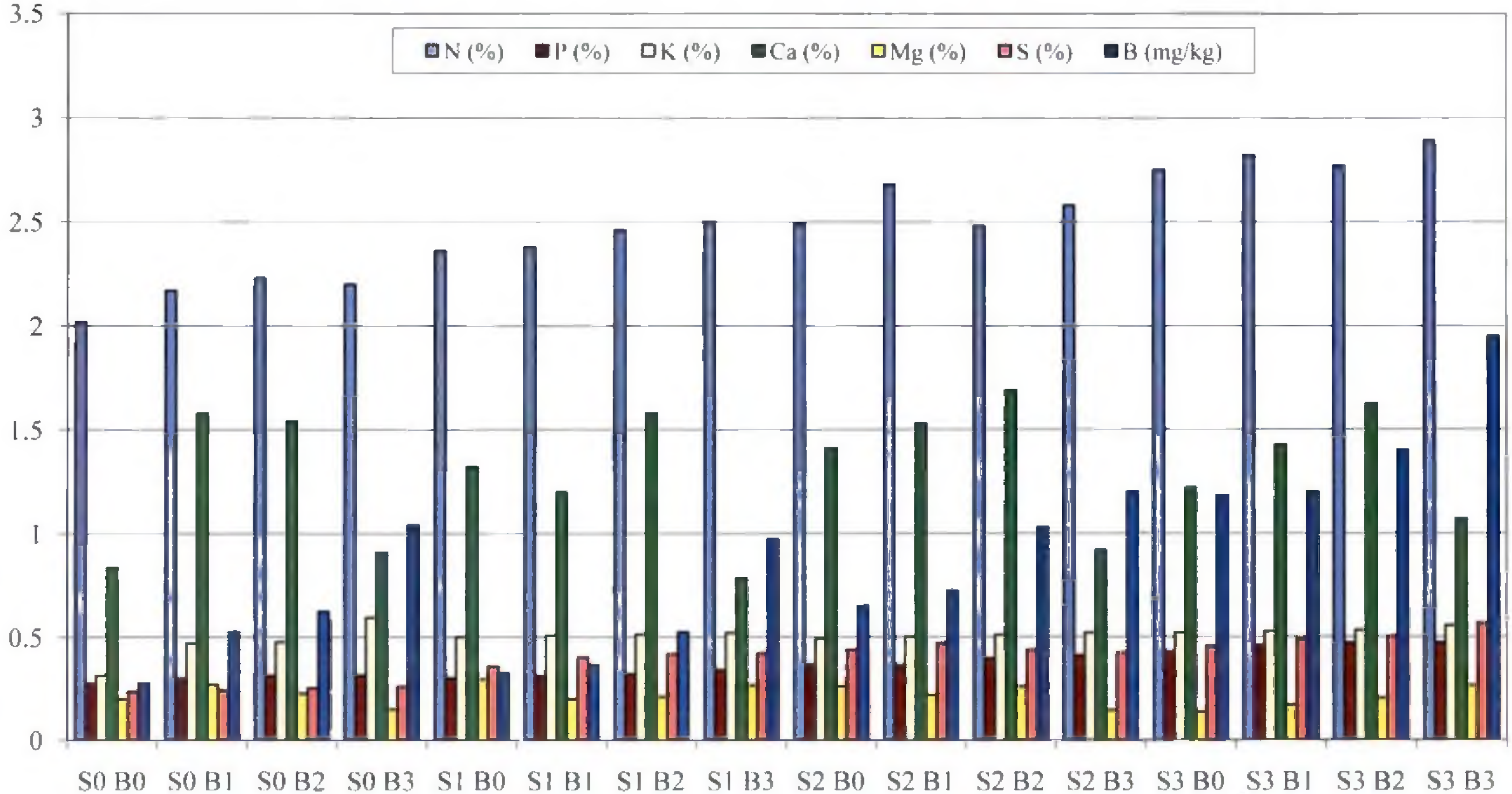

Fig. 14. Nutrient concentration of grain at harvest of the second crop

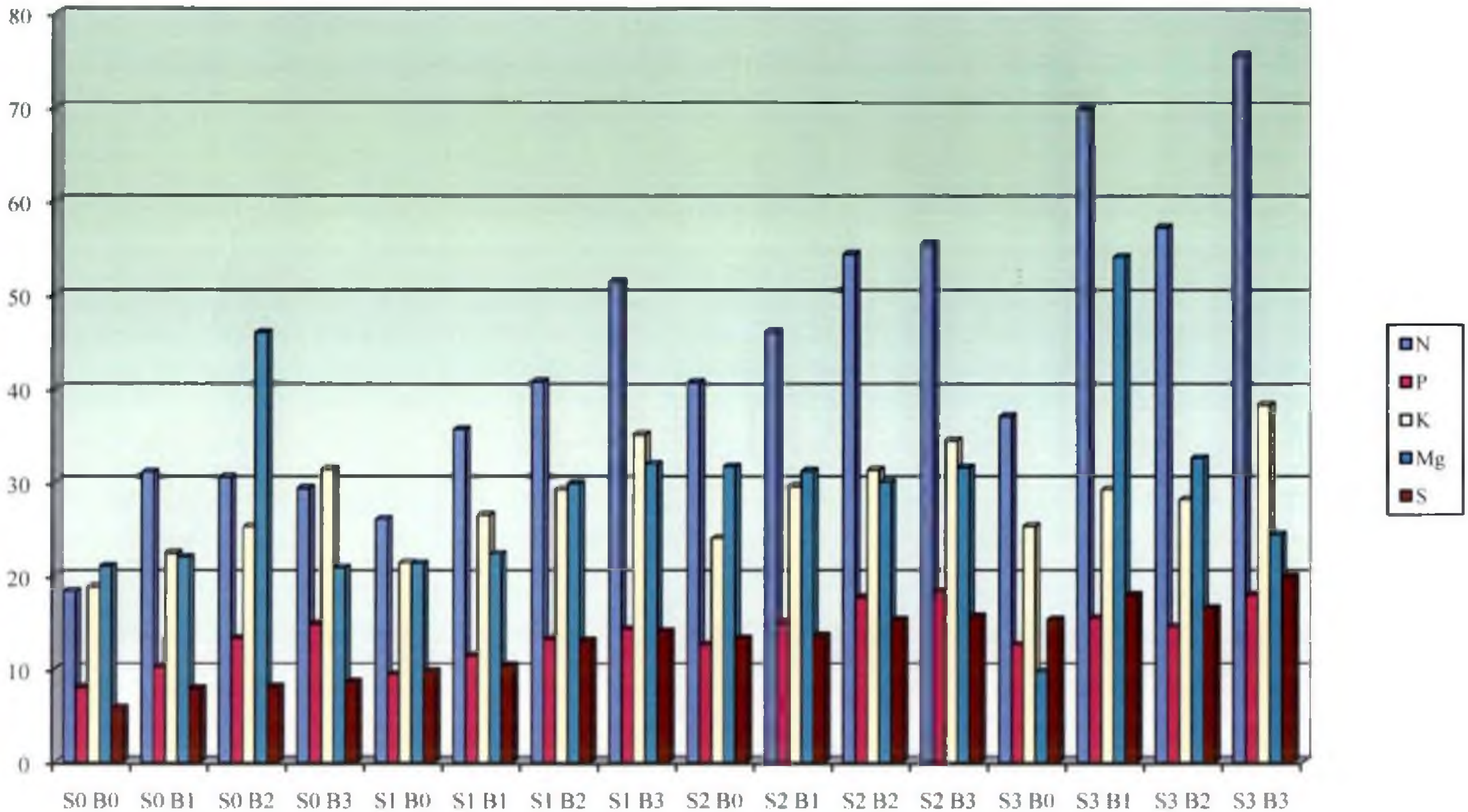

Fig. 15. Total nutrient uptake (Grain + Bhusa) at harvest of the first crop (kg ha^{-1})

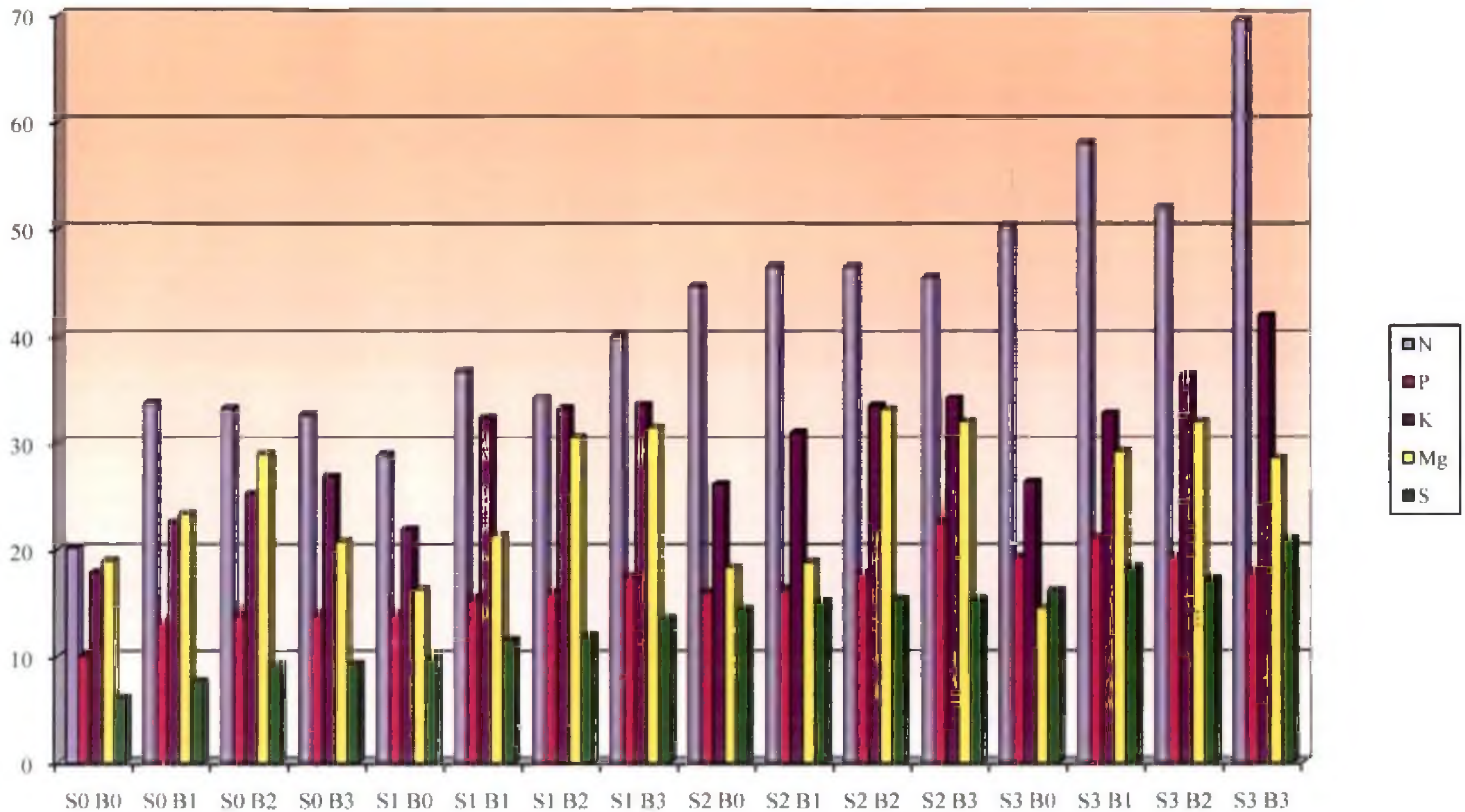

Fig.16. Total nutrient uptake (Grain + Bhusa) at harvest of the second crop (kg ha^{-1})

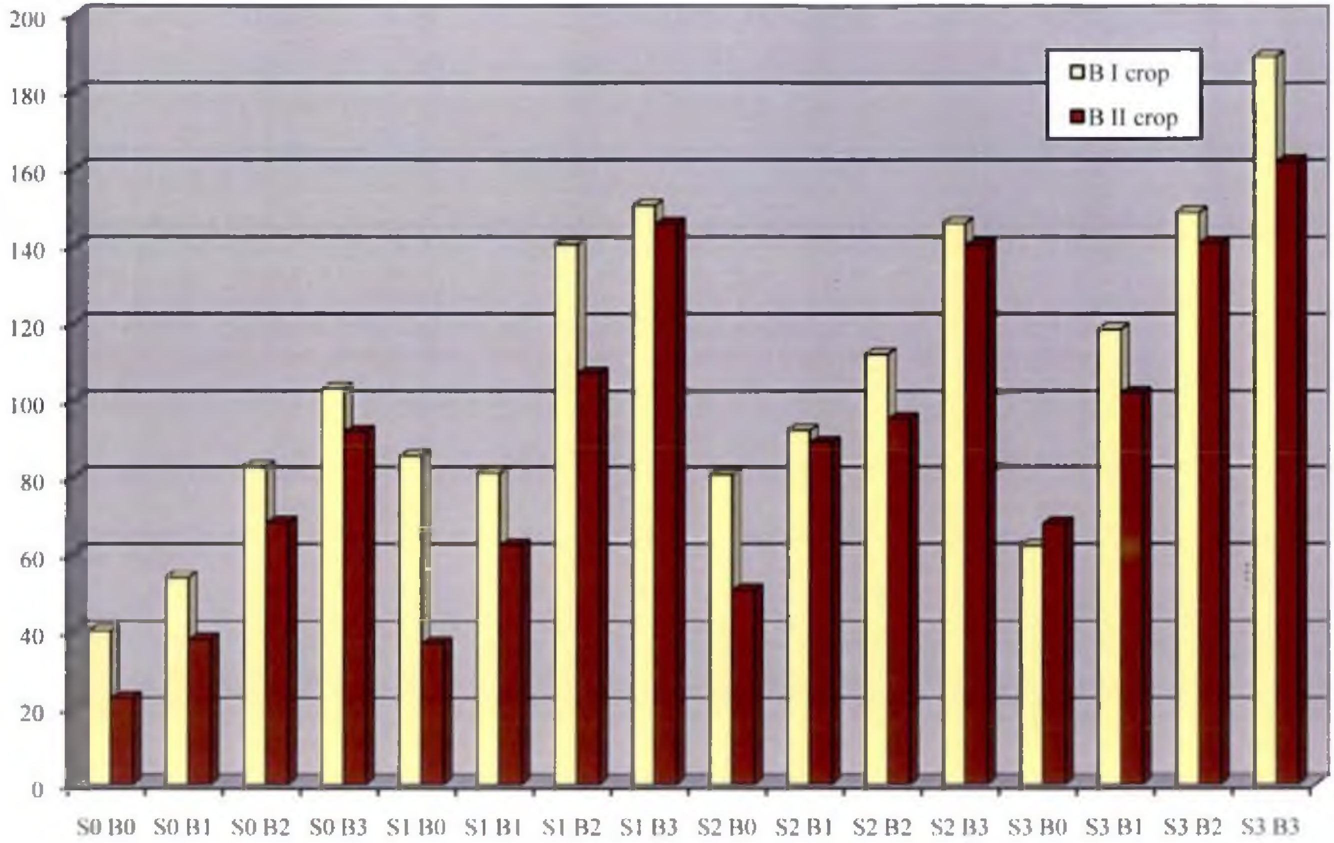

Fig. 17. Total B uptake (Grain +Bhusa) at harvest of the second crop (µg plant^{-1})

to improve the overall growth of the crop, it increased the total uptake although the magnitude of increase depends on the concentration and dry matter accumulation. Similar results were reported by Karthikeyan and Shukla (2008).

5.2.7 Nutrient Use Efficiency

5.2.7.1 S use efficiency

It had been observed from the data pertaining to the S use efficiency of the two field experiments that as the levels of S increased from 0 to 30 kg ha^{-1}, the use efficiency showed an increasing trend. In the second crop also, the same trend was observed. At higher levels of S application, the absorbed nutrients are efficiently utilized for grain formation. Similar result was reported by Sarkar and Saha (2005) and Piri and Sharma (2006).

5.2.7.2 Apparent S Recovery

As in the case of S use efficiency, the apparent S recovery also showed an increasing trend with increase in rate of S applied. This may be due to synchronization of judicious S supply with the crop demand so that efficient utilization of the nutrients is facilitated. This is also confirmed by the findings of Jena *et al*. (2006) in ground nut.

5.2.7.3 Boron Use Efficiency

In both the crops, the highest value for the B use efficiency was shown by B_1. With further increase in the level of B, a decreasing trend was observed. Hence we can conclude that efficient utilization of B in sesame is facilitated only up to 2.5 kg ha^{-1} and beyond which a negative trend is noticed which may be due to the ionic imbalance within the plant. This level can be inferred as the judicious one for sesame crop in Onattukara soil. The findings are in line with those of Sarkar and Saha (2005).

5.2.7.4 Apparent B Recovery

In both the field experiments, a decreasing trend with increase in level of applied B was noticed and the highest value in both cases were recorded by B_1(2.5 kg ha^{-1}).The trend was same as that of the B use efficiency of the crop. This also confirms the essentiality of applying 2.5 kg ha^{-1} B in sesame. Further increase in the level reduces the efficient recovery of applied B and hence it is economical to limit the application of B up to 2.5 kg ha^{-1}. This also supports the data on the crop yield. Similar findings in sesame was also reported by Sarkar and Saha (2005).

5.2.8 Effect of S and B on the available nutrient status of the soil at harvest of the crop (Fig.16 to 21)

The organic carbon content of the soil was significantly influenced by the application of different levels of S and B. S_3 and B_2 were the superior levels and T_{16} ($S_{30}B_{7.5}$) recorded the highest value of 0.479 per cent. The trend was similar in the second crop also. S_3 and B_3 recorded the superior value among the different levels of S and B. S and B might have improved the activity and population of soil microorganism which might have accelerated the decomposition of organic residues.

A significant and positive correlation between B and organic matter was reported by Kher and Isher (2006).

The available N content of the soil was also favourably influenced by the application of different levels of S and B. A positive trend was observed with regard to the increasing levels of S and B with regard to the available N status of the soil. T_{16} recorded the highest value in both the crops. S and B had been observed to have a synergistic effect with regard to the available N content of the soil.

In the case of available P, S_3 and B_3 showed the superior values and T_{16} (S_3B_3) recorded the highest value among the interaction between different levels of S and B. This clearly indicates the synergistic effect of

S and B on the available P status of the soil. Soluble sulphate from gypsum might have promoted the displacement of phosphate in soil and thus increased its availability.

The available K was also significantly influenced by the application of different levels of S and B. This may be due to the displacement of K by Ca from gypsum.

In the case of exchangeable Ca content, the S_3 and B_2 recorded the highest values. Among the interaction effect, T_{13} ($S_{30}B_0$) showed the highest value which clearly shows the positive influence of gypsum.

No definite trend was observed with regard to the exchangeable Mg content and the T_{10} (S_2B_1) registered the highest value followed by T_9 ($S_{15}B_0$). S_2 and B_1 were the superior levels.

The readily soluble sulphate radical from gypsum might have promoted the increase in the available S status of the soil. The solubility of gypsum is 1.6 g litre^{-1}. With increase in the levels of S, an increasing trend was observed. More over a synergistic relationship between S and B was also observed in the available S status of the soil.

In the case of available B, increasing level of applied B showed an increasing trend for the nutrient and the highest value was recorded by T_{16} ($S_{30}B_{7.5}$) followed by T_8 (S_1B_3). S_3 and B_3 were the superior levels showing their synergistic effect. Renukadevi *et al.* (2004) reported that B@ 2 kg ha^{-1} increased the available B status of the soil. Due to the improvement of the physical, chemical and biological properties of the soil, nutrient availability has been increased.

The availability of the micronutrients such as Fe, Mn and Zn were also significantly influenced by the application of different levels of S and B. It had been observed that increasing levels of S showed an increasing trend except in the case of Cu for which S_1 recorded the highest value. In the case of different levels of B, B_2 showed the highest values.

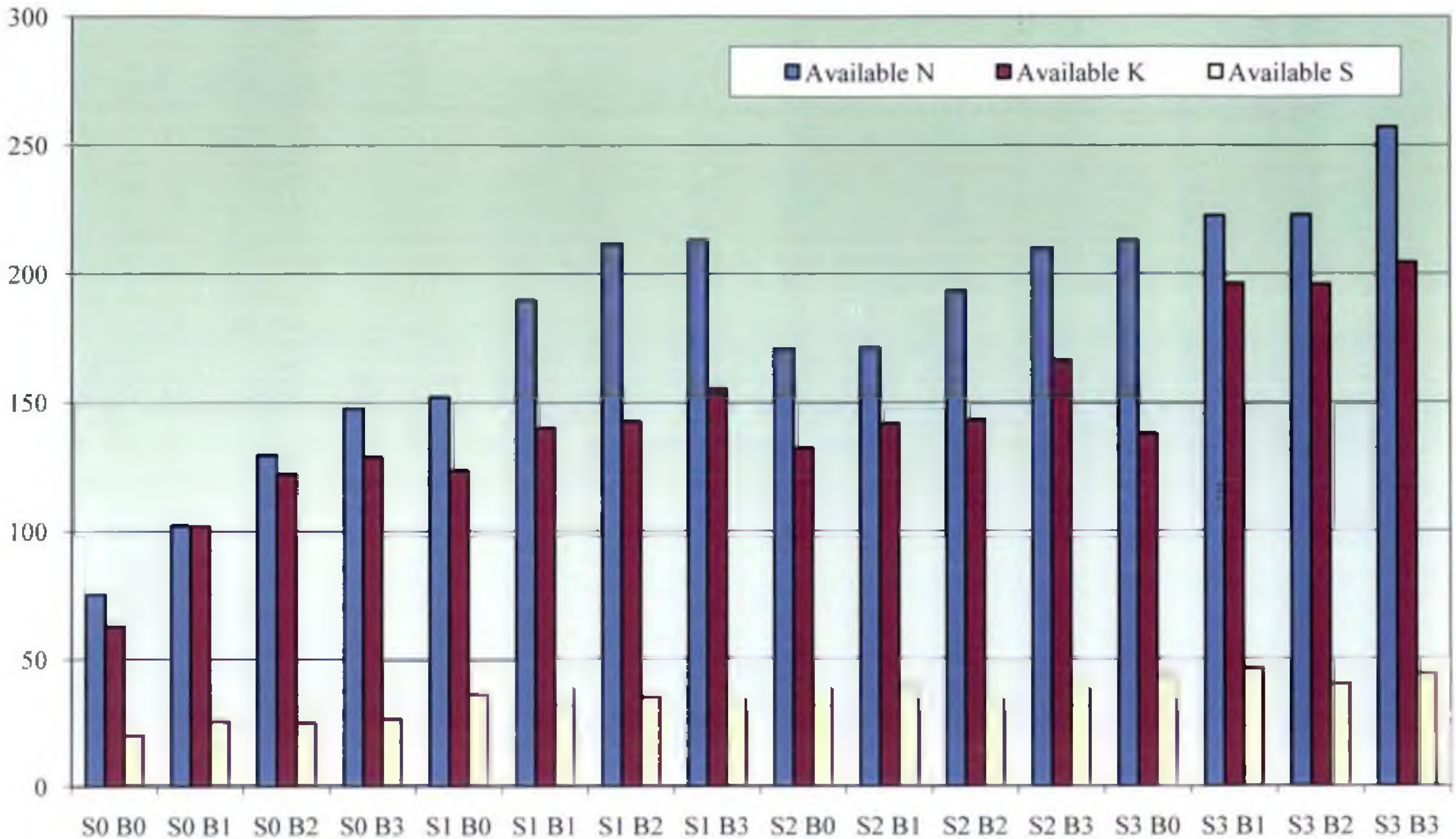

Fig. 18. Available N, K and S status of soil at harvest of the first crop (kg ha^{-1})

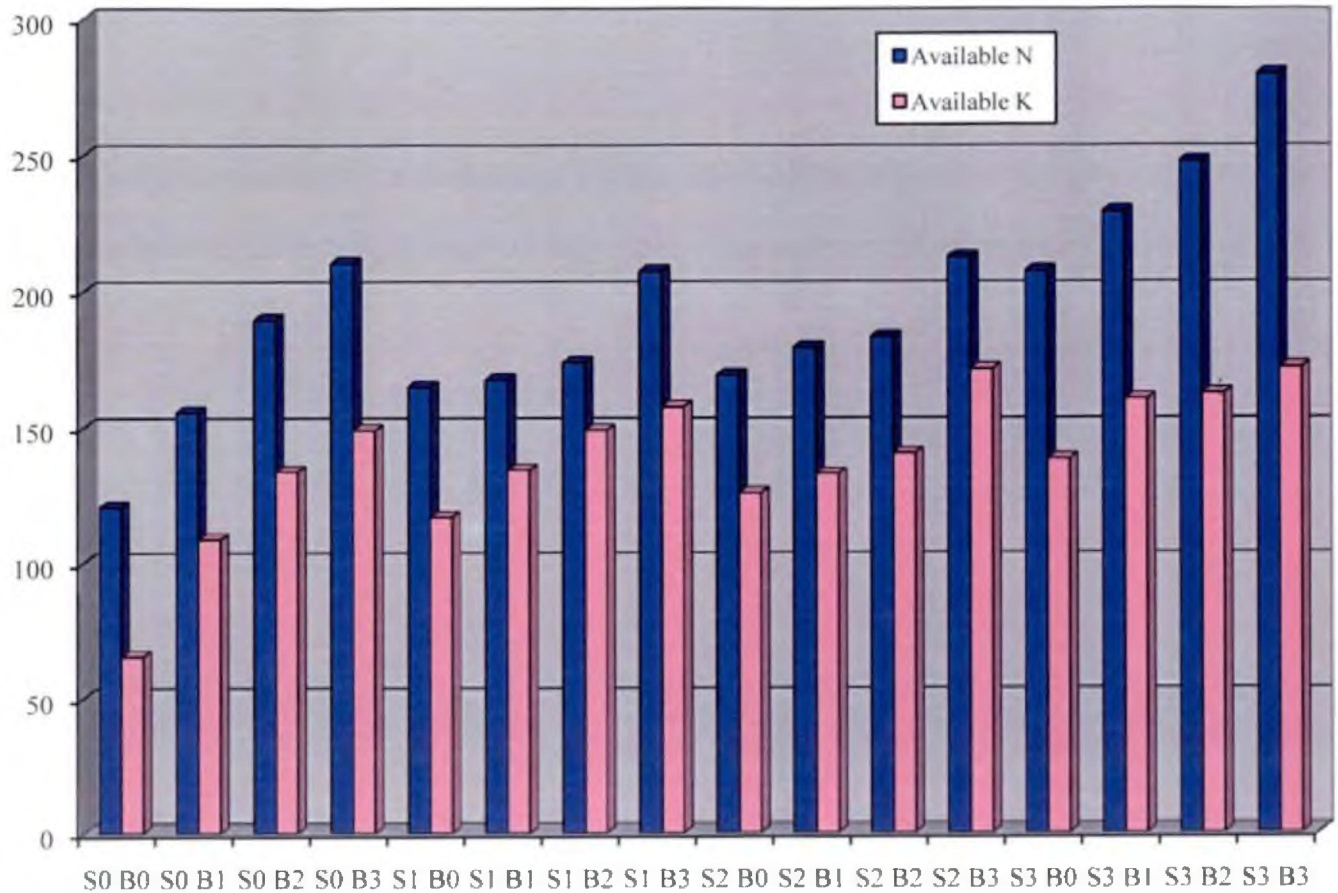

Fig. 19. Available N and K status of soil at harvest of the second crop (kg ha^{-1})

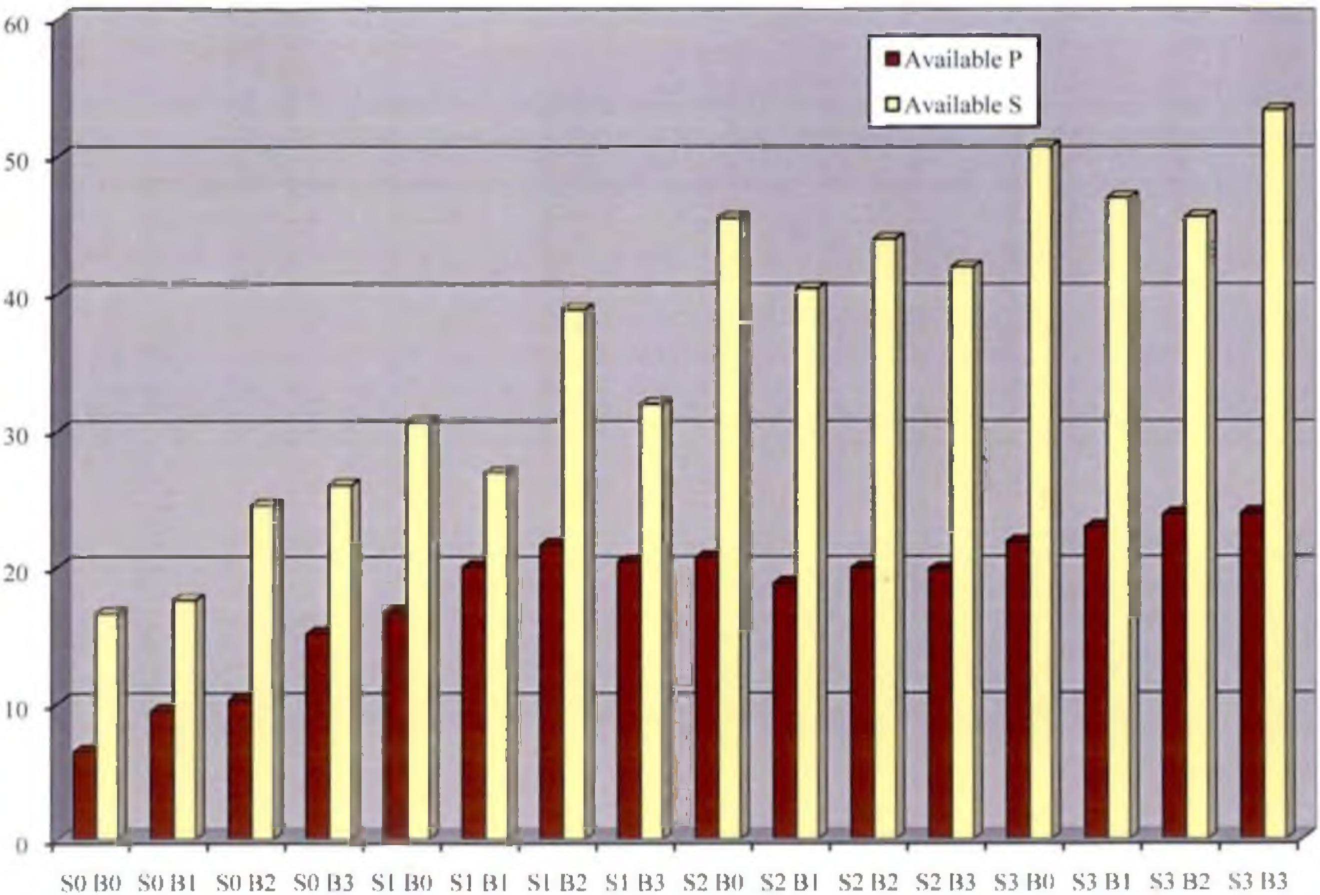

Fig. 20. Available P and S status at harvest of the second crop (kg ha^{-1})

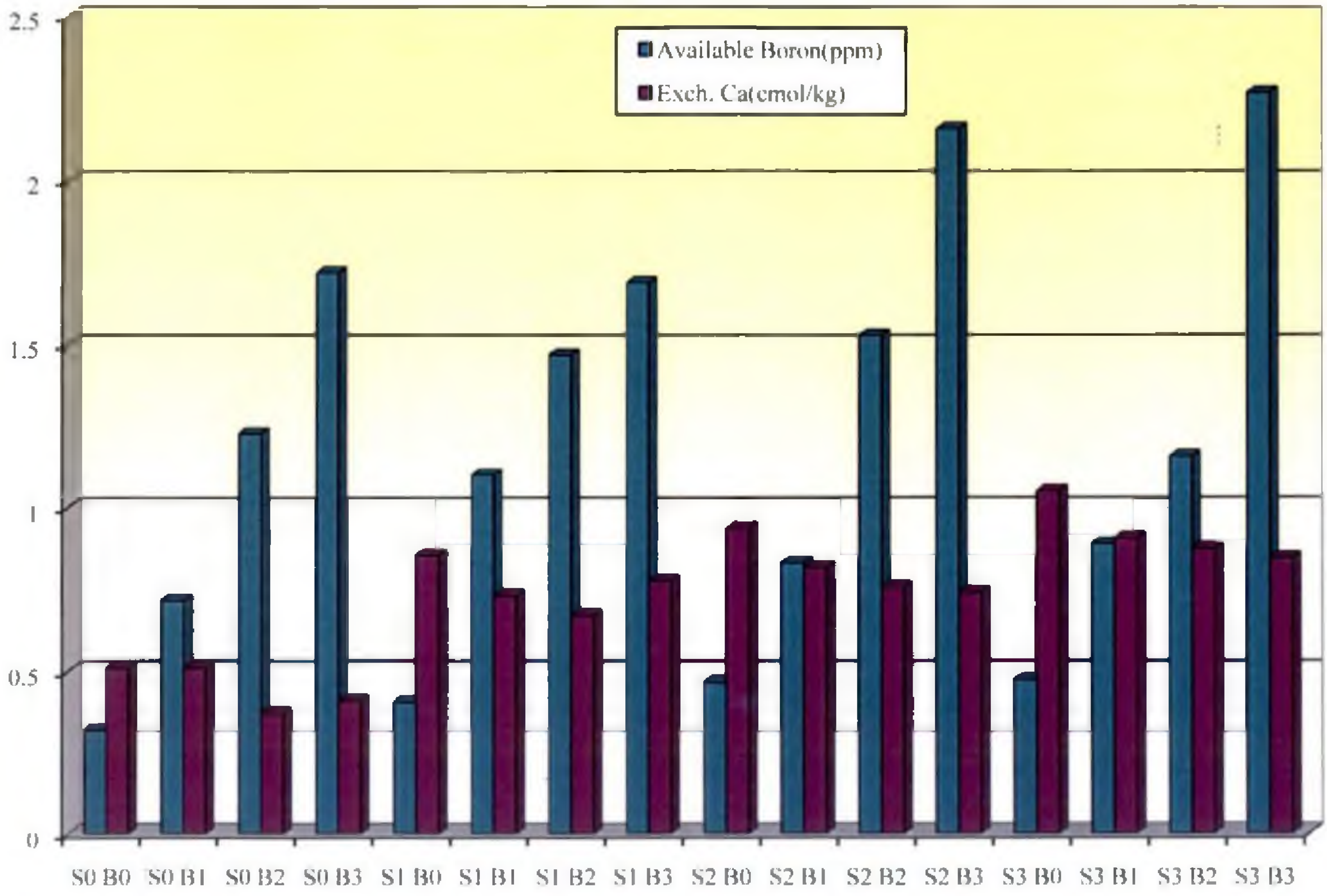

Fig. 21. Available B and exchangeable Ca of soil at harvest of the second crop

5.2.9 Standardisation of foliar diagnosis technique in sesame for S and B

Plant analysis, rated complementary to soil analysis is a useful realistic and practical tool for formulating fertiliser recommendations to crops. Whereas soil testing gives a measure of the potential availability of nutrients in soil to crops, plant analysis indicates the actual removal of nutrients by plants from the soil. A knowledge of the nutrient concentration in growing plants can serve as a tool for correcting any nutrient deficiency, if carried out early enough to safeguard yield. Between the two broad techniques of plant analysis and tissue analysis viz., whole plant analysis and tissue analysis, the latter has the advantage that it is more rapid and can cover a large number of plants scattered over a wide area with a relatively small volume of samples. Foliar diagnosis considered synonymous to tissue analysis is of the assumption that for each plant species certain plant parts will have uniform composition for at least a given period of time (Rao and Sekhon, 1989).

Lundegardh (1935) defined index part as that part of plant which gives the highest predictability on yield. This is on the assumption that there is an empirical relationship between the nutrient content of properly selected plant part and the final performance of the plant. According to Singh (2009) it is the lowest amount of nutrient in the plant accompanying the highest yield. Nielsen (1966) emphasised the need to identify the critical plant part and stage of sampling for the plant analysis results to be valid, as the nutrient concentration is dependent on several factors like part of the plant, growth stages of the crop, time of the day etc. Usually leaf is selected for foliar diagnosis being the focal point of all the biochemical functions of the plant. But other plant parts have also been indexed in some crops (petiole in banana, lamina in sunflower and brinjal, internode (stem) in alfalfa etc (Chapman, 1975).

As work on this line has not been carried out in sesame for any nutrient in Kerala or else where it was felt appropriate to include all the vegetative parts of the plant in the attempt to standardize the best part and growth stage of the crop for S and B status. Because of the short stature of the plants which makes sampling easy, the ontogeny or phyllochron of the leaves were not considered.

The identified sample plants were uprooted at the appropriate stages and segregated into different vegetative parts as shown below.

Plant Parts

Lamina

Petiole

Midrib

Internode

Stages of sampling

Stage I: 20 Days After Sowing	-	4-5 leaf stage
Stage II: 30 Days After Sowing	-	Branching stage
Stage III: 40 Days After Sowing	-	Flowering stage
Stage IV: 50 Days After Sowing	-	Pod formation stage

The samples were analysed for S and B contents which were related to sesame grain yield using quadratic regression model of the type $y = a + bx + cx^2$ where y is the yield and x the nutrient concentration (%) in the part. The extent of correlation between these parameters was also worked out. The values for correlation (r) obtained at each stage of the crop for each element under study are given below.

Table 38. Coefficient of correlation with S content

Plant Part	20 DAS	30 DAS	40 DAS	50 DAS
Lamina	0.359	0.264	0.459	0.436
Petiole	0.390	0.479	0.297	0.261
Midrib	0.276	0.366	0.195	0.384
Internode	0.302	0.427	0.367	0.472

Table 39. Coefficient of correlation with B content

Plant Part	20 DAS	30DAS	40DAS	50DAS
Lamina	0.446	0.496	0.319	0.136
Petiole	0.581	0.556	0.532	0.442
Midrib	0.391	0.436	0.455	0.324
Internode	0.368	0.439	0.409	0.333

The petiole recorded the highest r value for both the nutrients (0.479 for S and 0.581 for B) showing the maximum relationship with yield and it was selected as the best index for foliar sampling for S and B in sesame. Prevel *et al.*(1986) and Lanenegger and Du Plesser (1977) also observed that conducting tissues of plants especially petiole were useful indicators of tissue nutrients and suggested the choice of the plant as it is easier to define and locate a petiole sample than any other leaf part. Petiole as index part for foliar diagnosis has been reported for clover, soybean, banana, mango and papaya (Tandon, 1993).

Among the different growth stages of the crop the stage at which the selected index part (petiole) showed maximum correlation with yield as evidenced by the magnitude of value of coefficient of correlation was

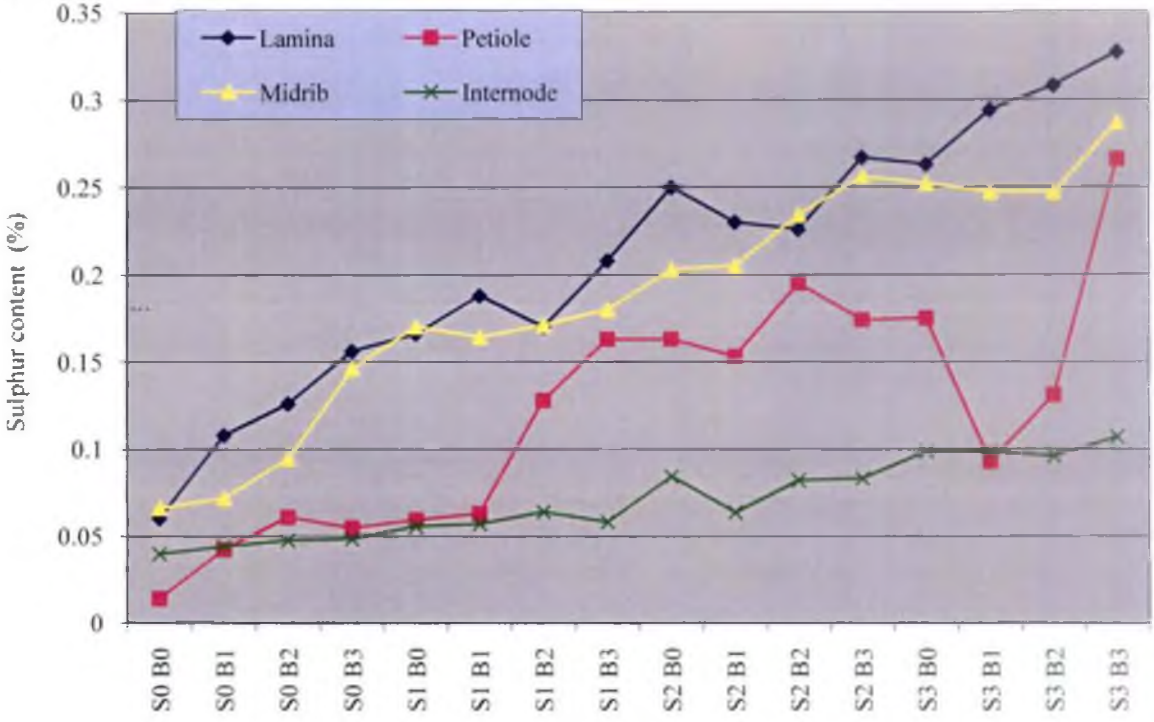

Fig. 22. S content of plant parts at 20DAS (%)

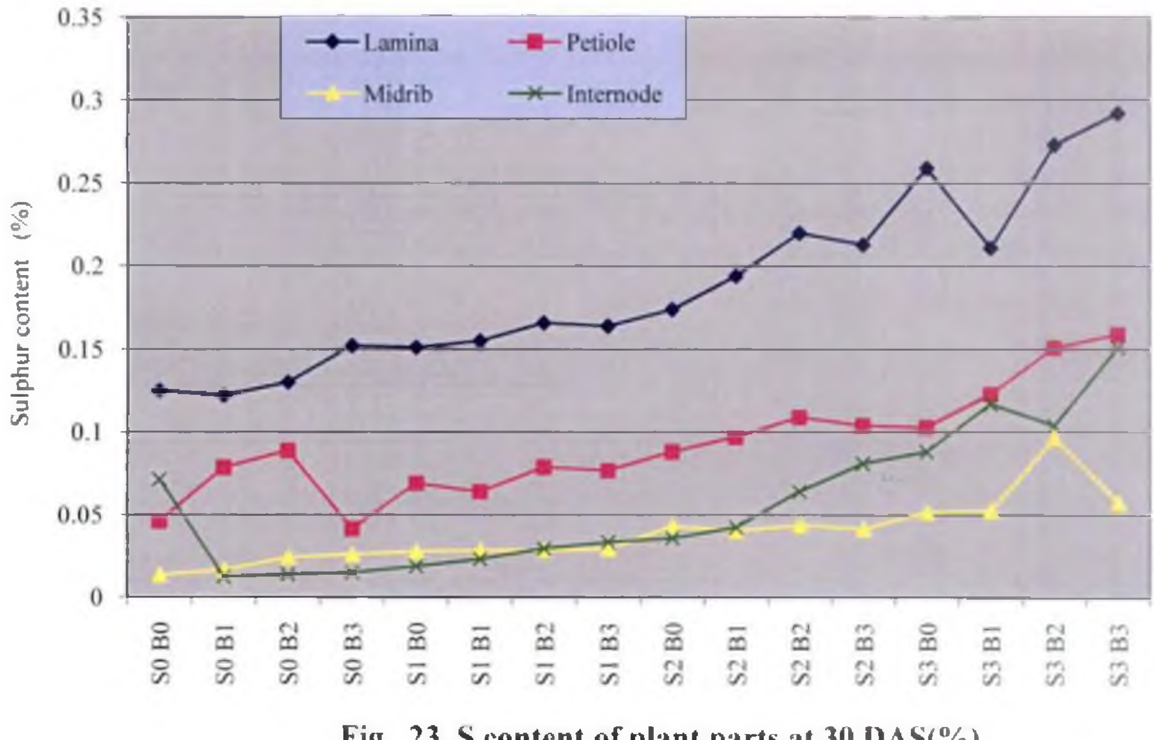

Fig. 23. S content of plant parts at 30 DAS(%)

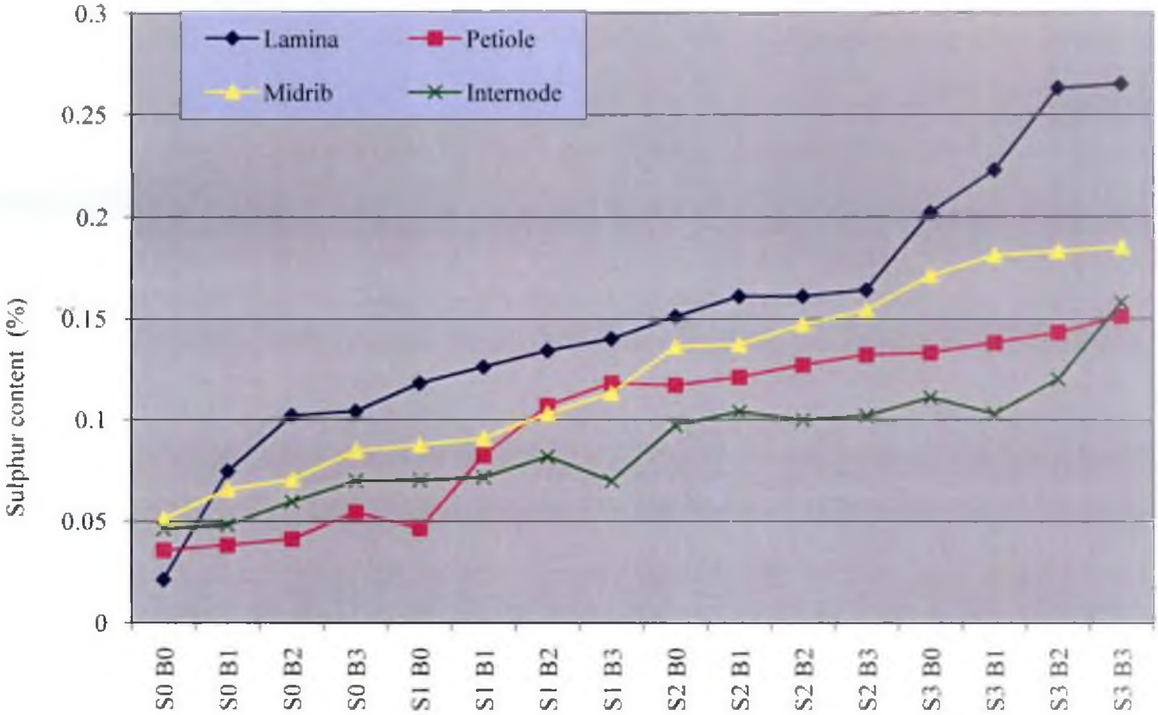

Fig. 24. S content of plant parts at 40 DAS (%)

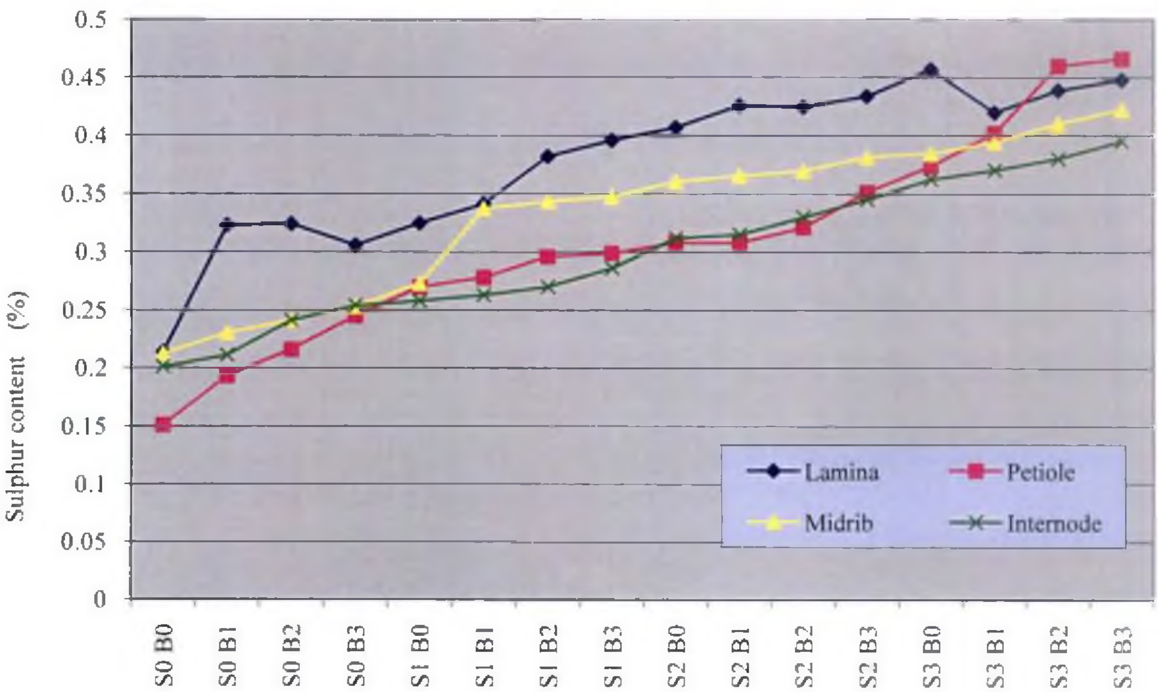

Fig. 25. S content of plant parts at 50 DAS (%)

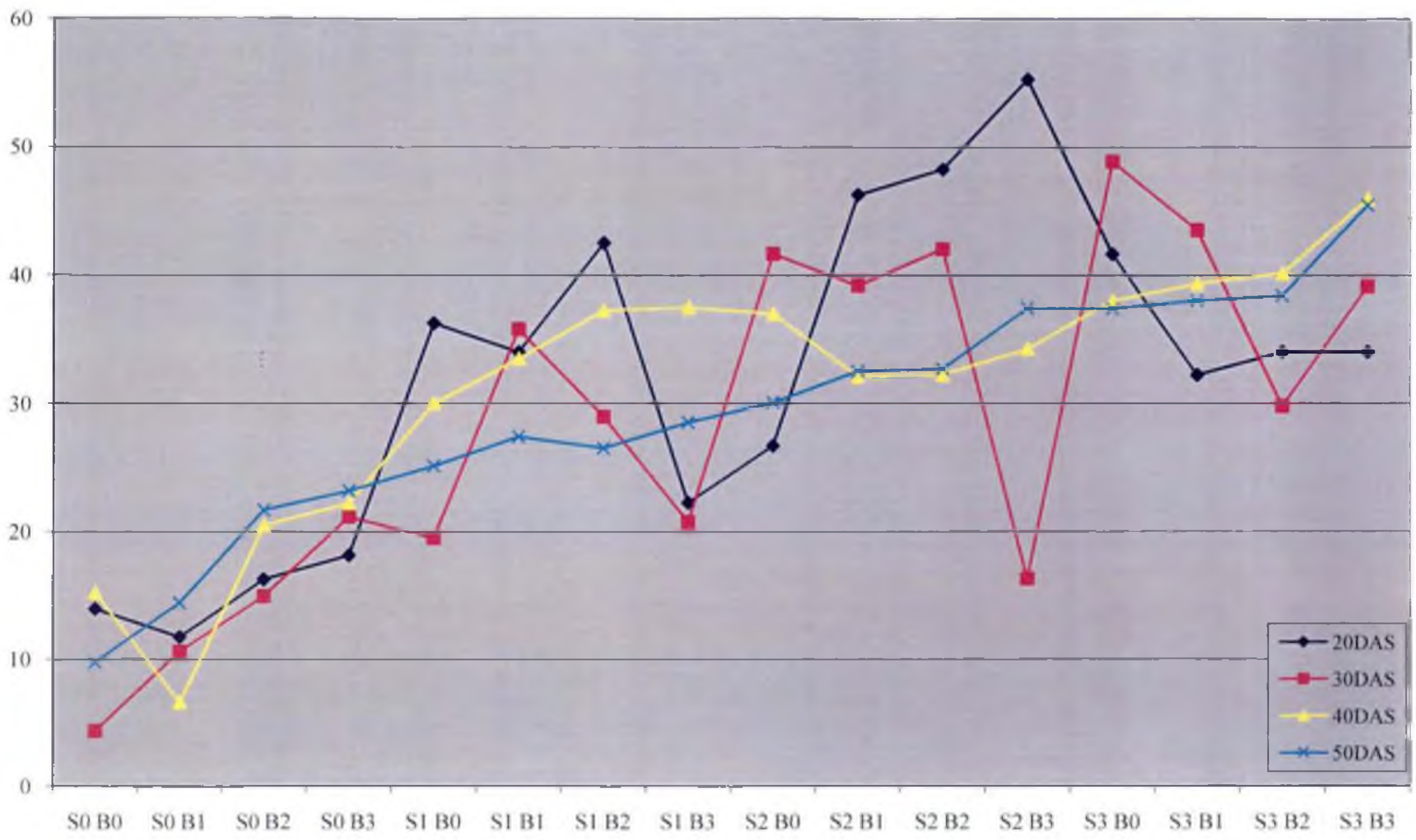

Fig.26 Available S of the soil at different sampling stages (kg ha^{-1})

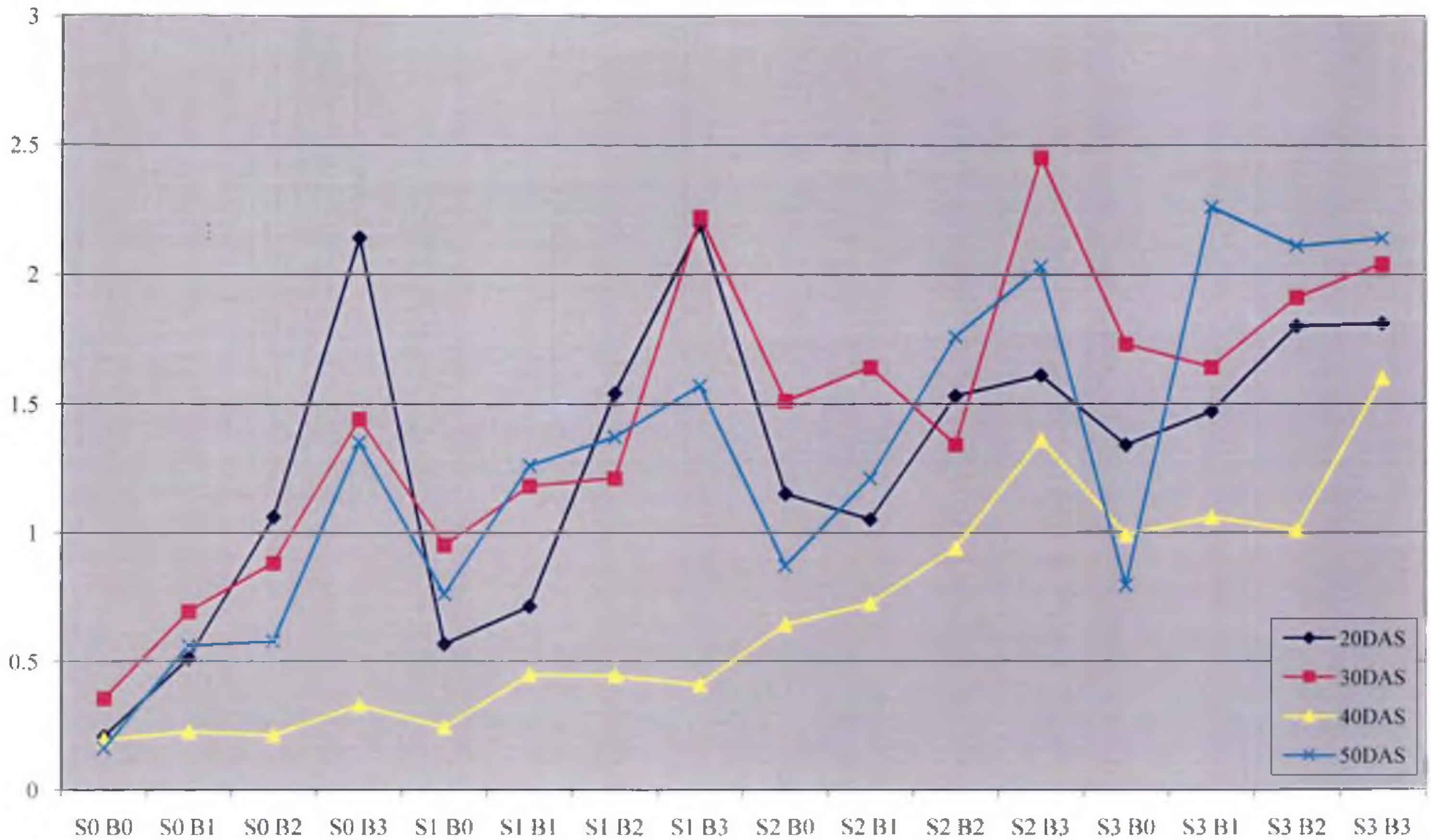

Fig.27 Available (Hot Water Extractable) B of soil at the different sampling stages (ppm)

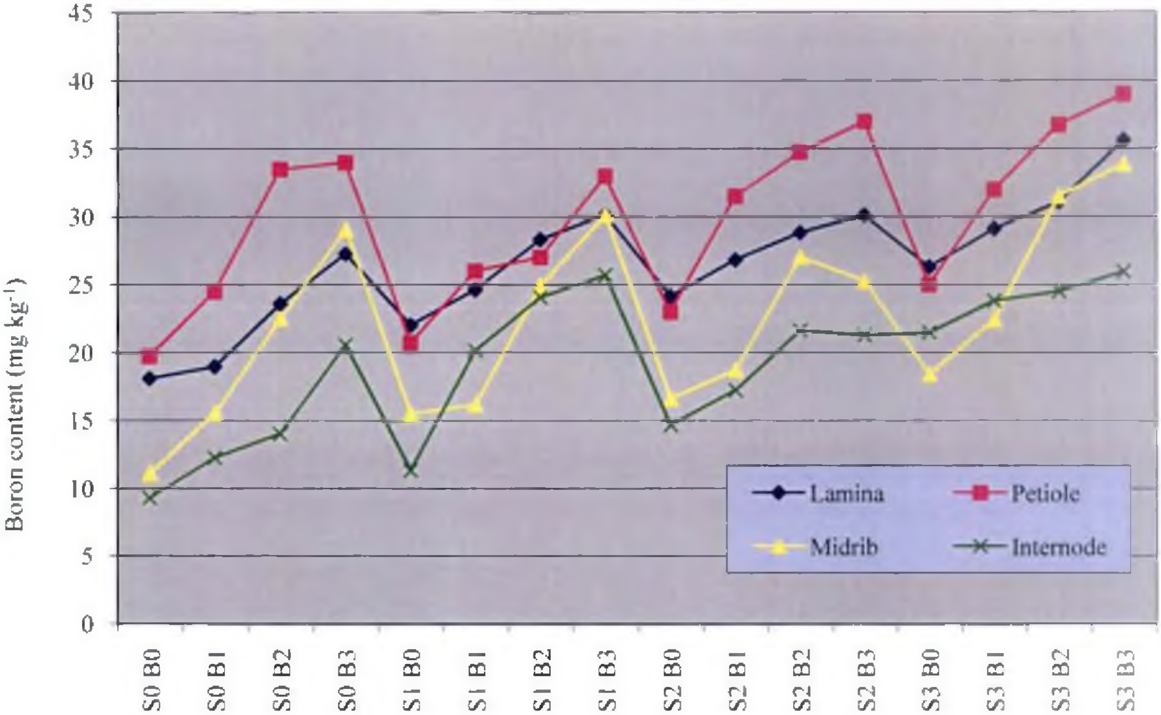

Fig. 28. B content of plant parts at 40 DAS (mg kg^{-1})

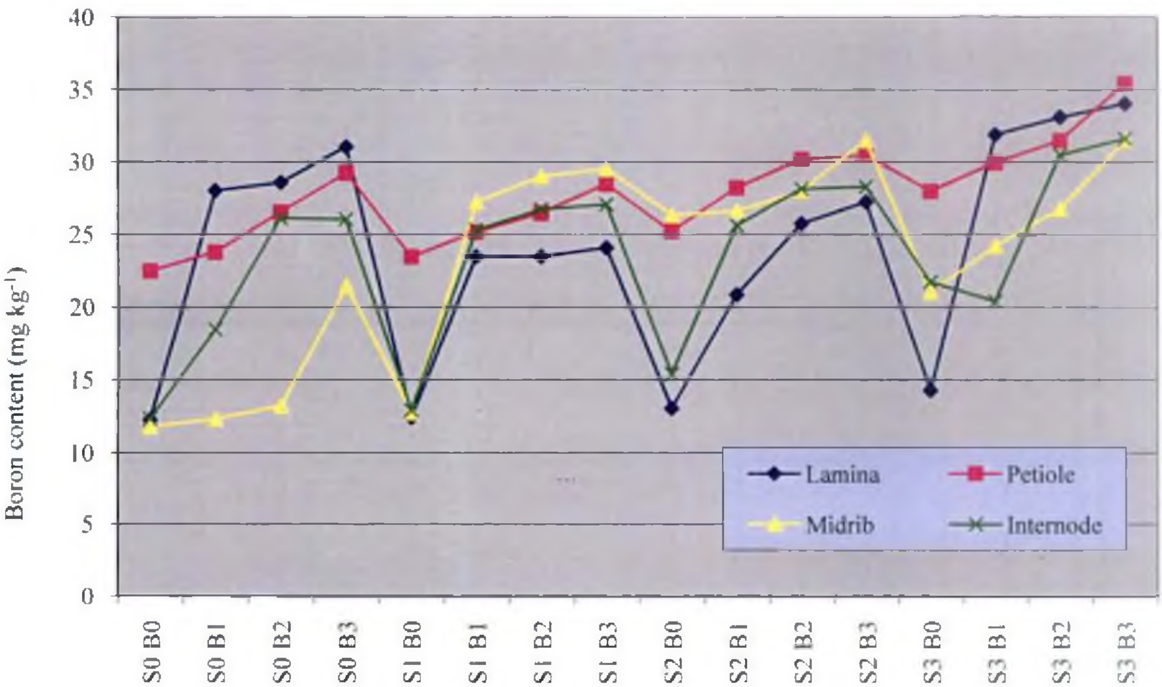

Fig. 29. B content of plant parts at 50 DAS (mg kg^{-1})

adjudged as the best stage of sampling for that particular nutrient. On this basis, the branching stage of sampling (30 DAS) was selected as the best stage of sampling for foliar diagnosis in sesame for S and 4-5 leaf stage (20 DAS) for B. This is of practical significance as both these stages coincide with the early vegetative phase of the crop when fertiliser application is feasible. On the basis of critical levels of these nutrients which have been worked out(given in the following section) the application schedule of these nutrients can be programmed so as to ensure the production of maximum number of primary and secondary branches which inturn will result in more number of pods and finally grain yield. As assured components of the plant composition at early stage of the crop, these nutrients can play their biochemical roles in oil synthesis also contributing to better oil yield quantitatively and qualitatively.

Critical S and B levels in petiole for maximum yield in sesame (Fig.30 and 31)

The critical levels of S and B in the index part (petiole) at the stages identified as the best. stage for sampling for each nutrient (30 DAS for S and 20 DAS for B) were determined adopting the scatter diagram technique of Cate and Nelson (1965). At each stage, graphs were plotted relating relative percentage yield values(Y axis) against the petiole S or B concentration (X axis) respectively. Using a plastic overlay the values were grouped into two populations constructing quadrants by drawing parallels, maximizing the number of points in the first and third quadrants. While drawing parallels, the concept of definition for critical level that it is the lowest nutrient levels accompanying the highest yield was taken as the guiding principle.

It can be observed from fig.30 that the critical petiole S content of sesame at 30 DAS for maximum yield is 0.088 per cent and from fig.31 that the critical petiole B content at 20 DAS for maximum yield is 28 mg kg^{-1}.

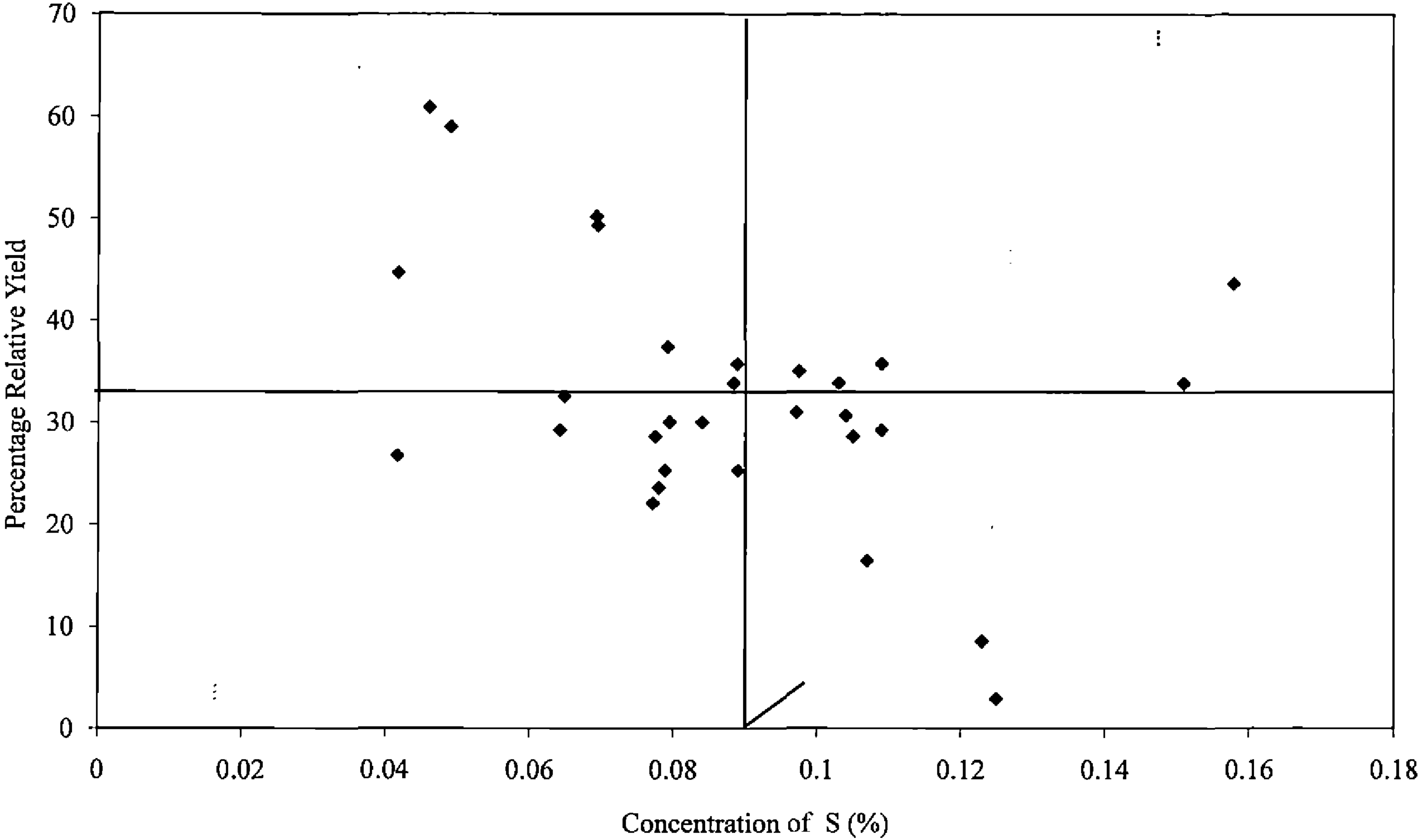

Fig. 30 Critical S level in petiole at 30 DAS

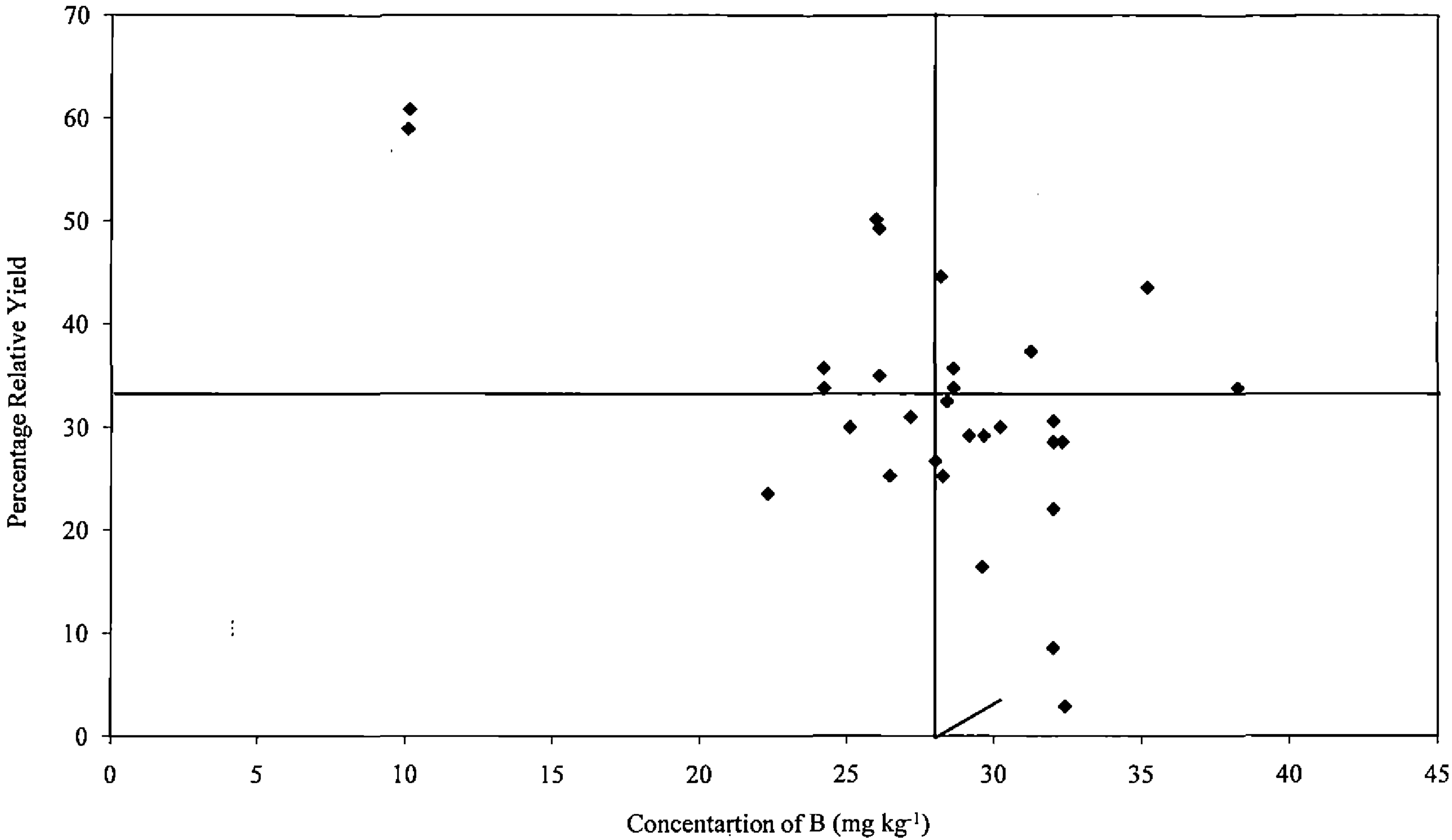

Fig. 31 Critical B level in petiole at 20 DAS

Soil Critical S and B levels for maximum yield in sesame (Fig 32 and 33)

For determining the critical levels of S and B in soil for maximum yield the stages of crop growth considered were the same as that for the foliar diagnosis of these nutrients. The procedure adopted was also the same (Cate and Nelson, 1965).

For deriving the soil critical S level relative percentage yields were plotted against soil available S contents at 30 DAS. For the soil critical B level, the relative percentage yields and the soil available B contents at 20 DAS were graphically related.

From the figures, it can be conclusively stated that for the maximum yield of sesame, in Onattukara sandy loam soil, the critical soil S level is 23 kg ha^{-1} at 30 DAS and the critical soil B level at 20 DAS is 1.4 ppm.

Paucity of work in similar lines makes comparison impossible. Basic analysis of the experimental soil shows a value of 10.2 kg ha^{-1} for available S and 0.18 ppm for available B which are below the critical levels. The results of the study highlight the scope of increasing the productivity of sesame in Onattukara region through S and B fertilization.

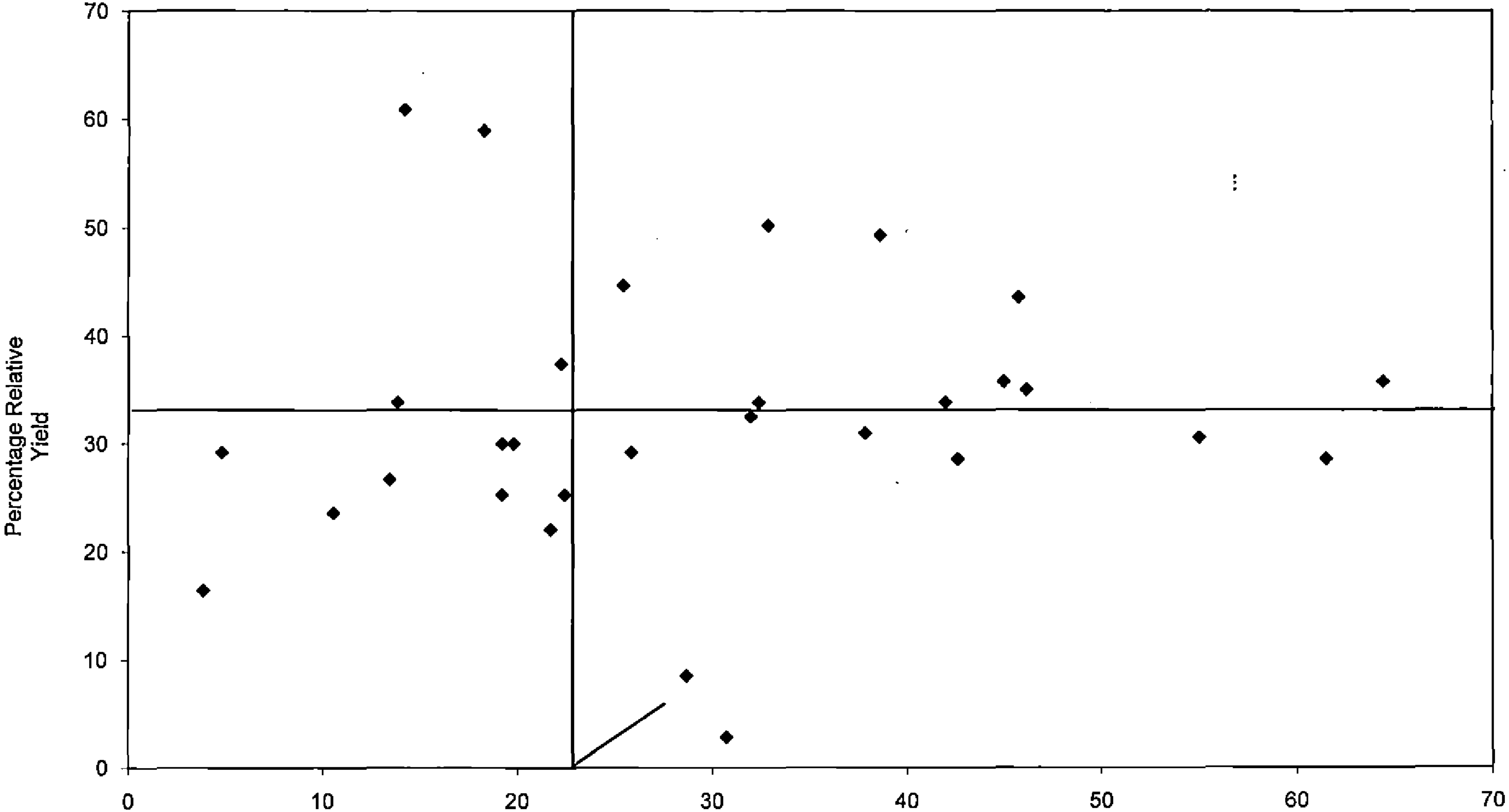

Fig. 32 Critical S level in soil at 30 DAS (kg ha^{-1})

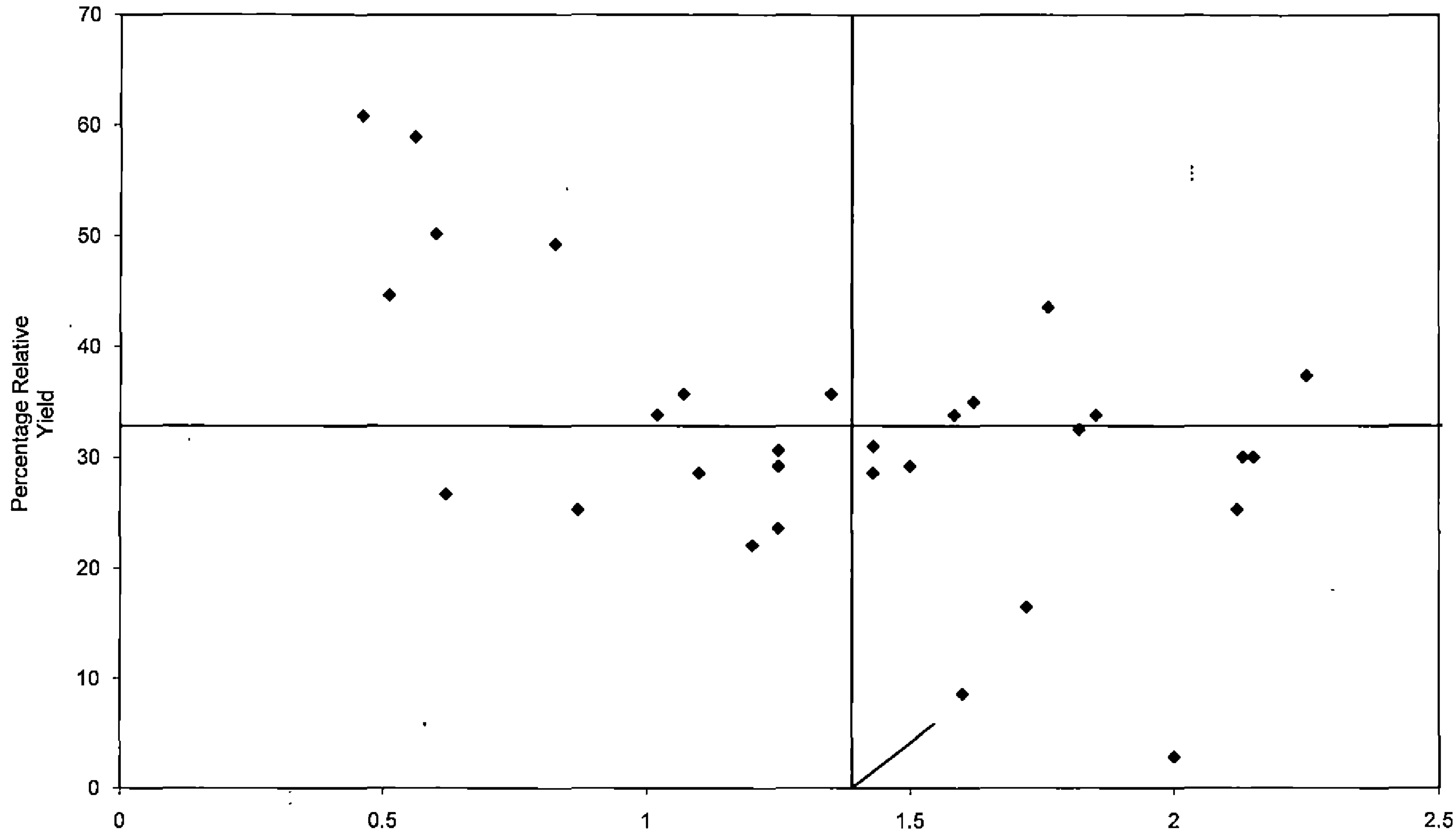

Fig. 33 Critical B level in soil at 20 DAS (ppm)

SUMMARY

6. SUMMARY

Detailed investigations consisting of laboratory incubation study and field experiments were carried out College of Agriculture, Vellayani and at Onattukara Regional Agricultural Research Station, Kayamkulam to understand the impact of S and B on the growth, yield and quality of sesame grown in sandy loam soils of Onattukara and also to standardize the index tissues and plant growth stage for the foliar diagnosis of these elements. The treatments consisted of $T_1(S_0B_0)$, T_2 $(S_0B_{2.5})$, $T_3(S_0B_{5.0})$, T_4 $(S_0B_{7.5})$, T_5 $(S_{7.5}B_0)$, T_6 $(S_{7.5}B_{2.5})$, T_7 $S_{7.5}B_{5.0})$, T_8 $(S_{7.5}B_{7.5})$, T_9 $(S_{15}B_0)$, T_{10} $(S_{15}B_{2.5})$, $T_{11}(S_{15}B_{5.0})$, T_{12} $(S_{15}B_{7.5})$, T_{13} $(S_{30}B_0)$, T_{14} $(S_{30}B_{2.5})$, T_{15} $(S_{30}B_{5.0})$, T_{16} $(S_{30}B_{7.5})$. The different levels of S were S_0 (0 kg S ha^{-1}), S_1 (7.5 kg ha^{-1}), S_2, (15.0 kg S ha^{-1}) and S_3 (30.0 kg S ha^{-1}). The levels of B include B_0 (0 kg B ha^{-1}), B_1 (2.5 kg B ha^{-1}) , B_2 (5.0 kg B ha^{-1}) and B_3(7.5 kg B ha^{-1}). The results of the study are summerised below.

- The incubation study was undertaken to analyse the release pattern of S and B from their sources viz. gypsum and borax in the soil at different sampling stages such as 20, 30, 40 and 50 DOI. It had been observed that the availability of both these nutrients were maximum at the 30^{th} DOI and there after showed a decreasing trend towards the end of incubation period. T_{16} $(S_{30}B_{7.5})$ recorded the highest value at all the sampling stages for S whereas, in the case of B, the treatment combinations which received B at the highest level in combination with S_3 or S_2 showed the maximum value.

- The crop growth characters were significantly influenced by the application of different levels of S and B. Increasing levels of S showed a positive influence on the growth characters like height, number of primary and secondary branches $plant^{-1}$, root spread and root volume. In the case of B, the synergistic influence along with S was reflected for most of the characters at 2.5 kg ha^{-1}.

- The yield and yield attributes of sesame also showed an increasing trend with increasing levels of S. But a decreasing trend with increasing levels of B was observed. However, the levels of S showed a steady increase in the yield up to 30 kg ha^{-1}. T_{16} ($S_{30}B_{7.5}$) recorded the highest value of 1460.94 kg ha^{-1} but was on par with T_{14} ($S_{30}B_{2.5}$). In the second year, T_{16} ($S_{30}B_{7.5}$) was found to be significantly superior over the other treatment combinations. But on economic analysis, of the data, T_{14} ($S_{30}B_{2.5}$) was found to be the most economical recording a B: C ratio of 4.52 and was found to be on par with T_{16} ($S_{30}B_{7.5}$).

- As regard to the oil constants, the acid value showed a decreasing trend with increasing levels of S and B. The lowest value of 2.00 was shown by T_{16} ($S_{30}B_{7.5}$). A decreasing trend was observed with regard to the saponification value also and the lowest value of 177.86 was shown by T_{16} ($S_{30}B_{7.5}$). In the case of iodine value T_{14} ($S_{30}B_{2.5}$) showed the highest value of 125 and a positive trend was observed with increasing levels of S and B.

- The content of saturated fatty acids such as palmatic acid and stearic acid decreased with increasing levels of S and B where as the content of unsaturated fatty acids such as oleic acid and linoleic acid showed an increasing trend with increasing levels of S and B.

- Application of different levels of S and B significantly enhanced the nutrient content in bhusa and grain of sesame. With regard to the N content in bhusa and grain, S_3 (30 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the superior levels for both bhusa and grain. T_{16} ($S_{30}B_{7.5}$) registered the highest value which was on par with T_{14} ($S_{30}B_{2.5}$) The total uptake also followed the same trend.

- T_{12} ($S_{15}B_{7.5}$) showed the highest value with regard to the P content in bhusa, whereas in the case of grain the highest value was observed in T_{16}. S_2 and B_3 were the superior levels with regard to the P content of bhusa, where as S_3 (30 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the highest value in the case of grain. The total uptake was highest for T_{16} ($S_{30}B_{7..5}$) and with regard to the individual effects, S_3 (30 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the superior levels.

- In the case of K content, T_{16} showed the highest value in the case of bhusa and S_3 and B_2 were the superior levels and the trend was same for the total uptake also. Among the individual effects, the highest values were shown by S_3 (30 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}). In the case of grain concentration also, T_{16} ($S_{30}B_{7.5}$) recorded the superior value and S_3 (30 kg S ha^{-1}) and B_2 (5.0 kg ha^{-1}) were the levels which recorded the highest values.
- Regarding the concentration and uptake of Ca, T_{13} ($S_{30.0}B_0$) recorded the highest value for bhusa and T_{11} ($S_{15}B_{5.0}$) for grain. S_2 (15.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) were the superior levels of S and B. In the case of total uptake, T_{13} ($S_{30.0}B_0$) showed the highest value and S_3 (30 kg S ha^{-1}) and B_0 (0 kg B ha^{-1}) were the superior levels.
- The highest value for bhusa and grain with regard to the Mg content was shown by T_{14} and T_8 ($S_{7.5}B_{7.5}$) respectively. No significance was observed with regard to their individual effects. In the case of total uptake trend was same as that of bhusa and S_3 (30 kg S ha^{-1}) and B_1 (2.5 kg ha^{-1}) were the superior levels.
- In the case of S content in bhusa and grain and the total uptake a positive influence of increasing levels of S and B were observed and the highest value was shown by T_{16} ($S_{30}B_{7.5}$). S_3 (30 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the superior levels of S and B.
- The B content of bhusa and the total uptake also showed an increasing trend with increasing levels of S and B. But in the case of grain concentration T_8 ($S_{7.5}B_{7.5}$), showed the highest value. The concentration and uptake of micronutrients also showed a significant influence towards the application of different levels of S and B.

- The S use efficiency and apparent S recovery showed an increasing trend with increasing levels of S and the maximum was noticed with S_3 (30.0 kg S ha^{-1}). However in the case of B, B use efficiency and apparent B recovery showed an increasing trend up to B_1(2.5 kg B ha^{-1}) and there after showed a decreasing trend.

- The available nutrient status of the soil after harvest of both the crops was also significantly influenced by the application of different levels of these nutrients. The organic C content showed an increasing trend with increasing levels of S and B. The highest value in the case of interaction between different levels of S and B was recorded by T_{16}. But as regard to the individual effects of these nutrients, S_3 (30.0 kg S ha^{-1}) and B_2 (5.0 kg B ha^{-1}) recorded the highest values.

- The available N content of the soil also recorded the same trend and the highest value was recorded by T_{16} ($S_{30}B_{7.5}$). In the case of individual effects, S_3 (30.0 kg. S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) showed the comparatively superior values.

- An increasing trend with increasing levels of S and B was observed with regard to the available P and K content of the soil. In this case the highest value with regard to the interaction between different levels of S and B was shown by T_{16} and among the individual effects, S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) recorded the maximum values. In the case of exchangeable Ca content of the soil, increasing levels of S showed a positive trend, whereas in the case of B, the highest value was obtained at the lowest B level. No definite trend was observed with regard to the exchangeable Mg content of the soil.

- The available S content was significantly and positively influenced by the increasing levels of S and B. T_{16} recorded the highest value and S_3 (30.0 kg S ha^{-1}) and B_3 (30.0 kg S ha^{-1}) were the superior levels of S and B. Similar trend was observed in the case of available B status of the soil.

- In the case of DTPA extractable micronutrients, the Fe and Mn contents were enhanced by the increasing levels of S, but regarding the different levels of B, Mn content was maximum at 2.5 kg ha^{-1}. In the case of Cu, the positive trend was observed with regard to the levels of B whereas, the highest value among the different levels of S was shown by S_1. The trend was same for the Zn content of the soil also.

- The soil samples were also taken for the analysis of S and B at the different sampling stages and the correlation between content and yield was also worked out. It had been observed that the available S content of the soil showed an increasing trend with increasing levels of S and the maximum values were recorded at 30 DAS. S_3 (30.0 kg S ha^{-1}) and B_3 (7.5 kg B ha^{-1}) were the superior levels of S and B. in the case of B T_8 ($S_{7.5}B_{7.5}$), T_{12} ($S_{15}B_{7.5}$), and T_{16} ($S_{30}B_{7.5}$) recorded the highest value at the different sampling stages.

- Standardization of index part in sesame for foliar diagnosis for S and B status was done by correlating the nutrient concentration in the segregated plant parts such as lamina, petiole, midrib and internode at the different growth stages of the crop such as 20 DAS, 30 DAS, 40 DAS and 50 DAS to the yield values. The part which showed the closest correlation to yield as evidenced by the magnitude of coefficient of correlation was selected as the index part of that particular nutrient and its stage of sampling as the best stage for plant sampling.

- On the above basis, petiole at 30 DAS (branching stage) was adjudged as the index part in sesame for S status ($r = 0.479$) and petiole at 20 DAS (4-5 leaf stage) as the index part for B status ($r = 0.581$).

- The critical levels for S and B at 30 and 20 DAS respectively in the index part (petiole) for maximum yield in sesame were determined adopting the scatter diagram technique, plotting the relative percentage yield values against petiole S and B concentration. The critical petiole S level at 30 DAS for maximum production of sesame was found to be

0.088 per cent while the critical petiole B level at 20 DAS for maximum production is 28 mg kg^{-1}.

- The soil critical levels for maximum production at the stages identified to be the best for foliar diagnosis were worked out using the same statistical technique as adopted for determining the plant critical levels. Accordingly, the soil critical S level at 30 DAS for maximum production in sesame was found to be 23 kg ha^{-1} and the soil critical B level was 1.4 ppm at 20 DAS.

FUTURE LINE OF WORK

In the present study, S and B have been found to be positively influencing the sustainable production of sesame in the Onattukara region of Kerala. The investigations should also be repeated in farmer's plots and results should be compared so as to standardize the practices. Studies regarding the influence of other micronutrients on enhancing the productivity of sesame need to be carried out. The foliar diagnosis technique for these nutrients in sesame also need to be standardized.

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SULPHUR AND BORON NUTRITION AND THEIR FOLIAR DIAGNOSIS IN SESAME (*Sesamum indicum* L.)

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Abstract of the
thesis submitted in partial fulfilment of the requirement
for the degree of

Doctor of Philosophy in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

2009

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ABSTRACT

A laboratory cum field experiment was conducted to study the effect of S and B on the growth, yield and quality of sesame var. Thilarani and to standardize the foliar diagnosis of these elements in Onattukara sandy loam soil. The study included an incubation study and two field experiments. The treatments comprising the different levels of S and B laid out in 4^2factorial RBD. The treatments were $T_1(S_0B_0)$, $T_2(S_0B_1)$, $T_3(S_0B_2)$, $T_4(S_0B_3)$, $T_5(S_1B_0)$, $T_6(S_1B_1)$, $T_7(S_1B_2)$, $T_8(S_1B_3)$, $T_9(S_2B_0)$, $T_{10}(S_2B_1)$, $T_{11}(S_2B_2)$, $T_{12}(S_2B_3)$, $T_{13}(S_3B_0)$, $T_{14}(S_3B_1)$, $T_{15}(S_3B_2)$, $T_{16}(S_3B_3)$. The different levels of S were S_0 (0 kg ha^{-1}), S_1 (7.5 kg ha^{-1}), S_2, (15 kg ha^{-1}) and S_3 (30 kg ha^{-1}) and B_0 (0 kg ha^{-1}), B_1(2.5 kg ha^{-1}), B_2 (5 kg ha^{-1}) and B_3 (7.5 kg ha^{-1}).

The incubation study was conducted at College of Agriculture, Vellayani to understand the dissolution and release pattern of S and B from their sources gypsum and borax respectively in Onattukara sandy soil.

The results revealed that the release of S and B was maximum at the 30^{th} DOI. Increasing levels of S and B has a positive influence on the S content of the soil. T_{16} (S_3B_3) recorded the highest value at all the sampling stages for S whereas in the case of B, the treatment combinations which received B at the highest levels in combination with S_3 or S_2 showed the highest value.

The field experiments were laid out at ORARS, Kayamkulam in 4^2 factorial RBD having two replications using Thilarani as the test crop. It was observed that application of S and B favourably influenced the yield and yield attributes of sesame. T_{16} was found to be the treatment which gave the highest grain yield and oil yield in both the years and was found to be on par with T_{14} (S_3B_1). S_3 was the superior S level. As for the different levels of B, B_1 can be inferred as the best level.

The content of saturated fatty acids such as palmatic and stearic acid showed a decreasing trend with increasing levels of S and B whereas the content of the unsaturated fatty acids showed an increasing trend. The quality attributes of

oil such as acid value, iodine value and saponification value was also studied and it was found that there is a decreasing trend with regard to acid and saponification value and an increasing trend for iodine number. The grain protein content also showed an increasing trend with the increase in rate of application of S and B.

Regarding the content and uptake of N, P, K, S, B, Fe, Mn, Cu and Zn, a favourable influence for the different levels of S and B was recorded. Results regarding the S and B use efficiency and their apparent recovery showed that with increase in levels of S, an increasing trend was observed for S. In the case of B, increase was noticed up to B_1 (2.5 kg ha^{-1}) and there after showed a decreasing trend.

This positive influence was also reflected on the available nutrient status of the soil such as organic carbon content, available N, P, K, S, B and DTPA extractable micronutrients.

Correlation studies conducted to standardize the part and stage of sampling for the foliar diagnosis of sesame showed petiole at 30 DAS and 20 DAS in the case of S and B respectively. The same stages were found for the soil sampling also for both the nutrients.

The critical nutrient level in the part standardised for these two nutrients were standardized using the graphical method proposed by Cate and Nelson (1965). In the case of S, it had been standardized as 0.088 per cent and for B, it had been found to be 28 mg kg^{-1}. The critical nutrient level in soil was also estimated using the scatter diagram technique and was found to be 23 kg ha^{-1} at 30 DAS for S and 1.4 ppm at 20 DAS for B.

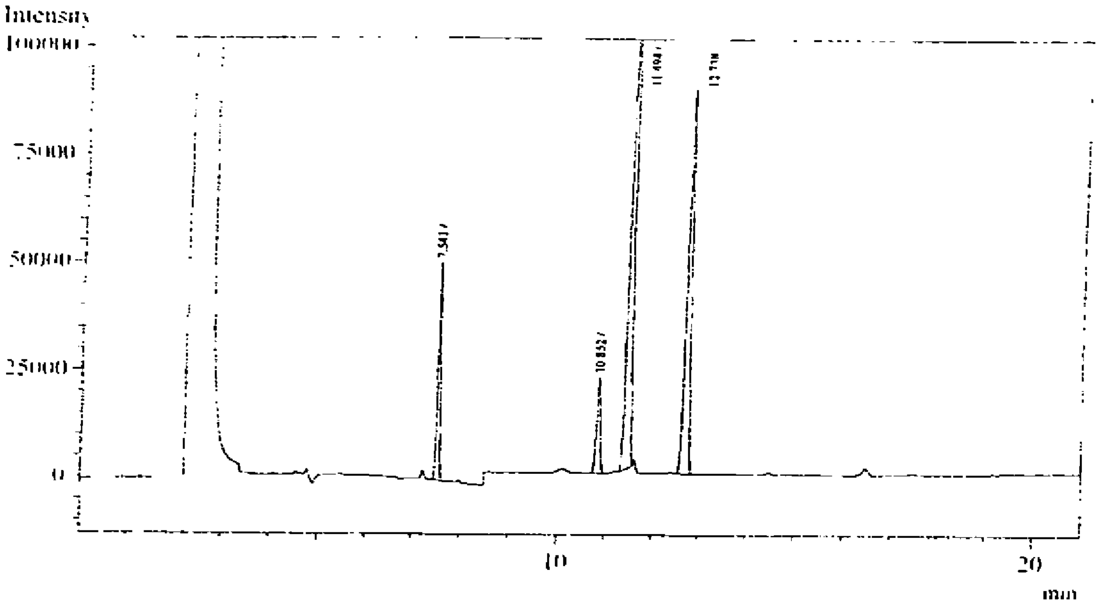
Hence the application of S @ 30 kg ha^{-1} and B @ 2.5 kg ha^{-1} could faourably enhance growth of sesame with regard to the growth characters, yield and yield attributes and the quality aspects. Moreover, analysis of the plant and soil samples at the critical stages fixed for the respective nutrients will provide the necessary data for the sustainable management of the crop in Onattukara sandy loam soil.

APPENDICES

APPENDIX – I

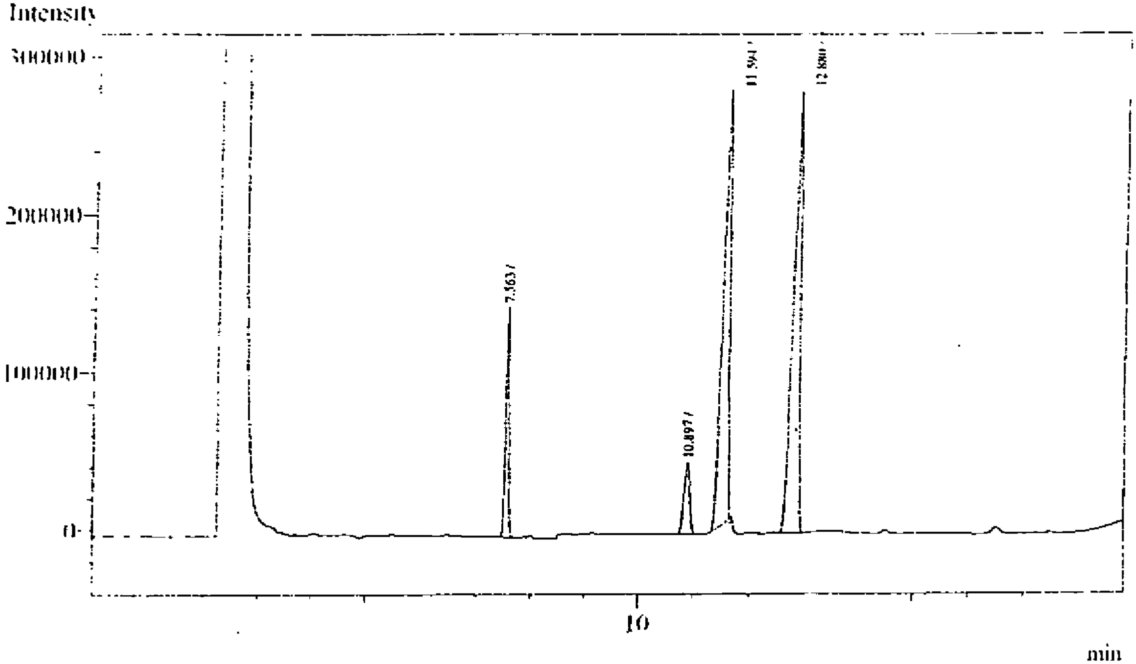
Weather parameters during February 2007 to May 2007 and Jan 2009 to April 2009

Standard weeks	Rainfall (mm)	Evaporation (mm)	Maximum temperature (^0C)	Minimum temperature (^0C)	Wet Bulb temperature (^0C)	Dry Bulb temperature (^0C)
Feb.2007						
1st week	0.00	17.86	32.00	20.86	22.57	24.57
2nd week	0.00	17.86	32.29	21.86	23.43	25.29
3rd week	3.57	44.00	31.57	22.43	23.86	25.57
4th week	0.00	20.86	32.00	20.57	23.29	26.00
Mar.2007						
1st week	0.00	19.86	32.00	22.29	25.00	27.29
2nd week	0.00	26.29	33.00	23.14	25.14	28.00
3rd week	1.29	23.14	33.00	25.14	26.43	28.71
4th week	0.00	28.29	33.00	26.43	27.14	29.71
5th week	0.00	19.67	33.00	25.67	26.67	29.00
Apr.2007						
1st week	0.66	15.86	34.14	26.43	27.57	29.86
2nd week	18.59	-139.14	31.57	24.57	25.86	27.71
3rd week	3.17	-3.57	33.00	24.57	26.57	29.29
4th week	2.46	-4.43	35.14	24.71	26.00	28.29
5th week	5.70	27.00	33.00	25.50	27.50	30.00
May.2007						
1st week	10.44	-76.86	32.57	25.86	27.14	29.00
2nd week	6.74	-51.43	31.14	26.29	26.86	28.57
3rd week	0.00	19.14	33.00	25.57	27.14	29.71
4th week	20.23	-40.86	32.71	26.29	27.29	29.29
5th week	30.40	-67.67	29.33	24.33	25.00	26.00
Jan 2009						
1st week	0.00	13.29	31.71	19.57	25.00	22.14
2nd week	0.00	13.71	32.29	21.57	26.00	22.14
3rd week	0.00	13.57	32.57	19.86	26.14	22.71
4th week	0.00	12.57	31.29	20.43	24.86	22.00
5th week	0.00	11.33	31.00	24.33	25.67	23.00
Feb.2009						
1st week	0.00	12.29	31.57	20.71	21.57	24.43
2nd week	0.00	11.57	31.57	20.71	21.29	25.43
3rd week	0.00	13.43	31.86	22.00	22.14	26.14
4th week	0.00	14.14	33.43	25.29	25.29	28.29
Mar. 2009						
1st week	0.00	15.29	32.29	24.71	26.00	29.00
2nd week	4.77	-37.29	32.14	23.86	25.29	28.43
3rd week	0.00	12.29	32.57	24.57	25.57	28.57
4th week	0.26	15.00	32.43	24.29	25.29	28.71
5th week	0.60	16.67	33.33	25.67	25.33	29.33
Apr. 2009						
1st week	1.29	2.57	34.14	25.71	26.29	29.86
2nd week	6.14	-28.81	31.57	25.14	24.86	26.57
3rd week	4.14	-5.86	31.57	25.71	26.57	28.43
4th week	0.40	10.43	32.71	26.00	26.57	29.29
5th week	26.00	-74.00	33.00	25.50	28.50	30.50



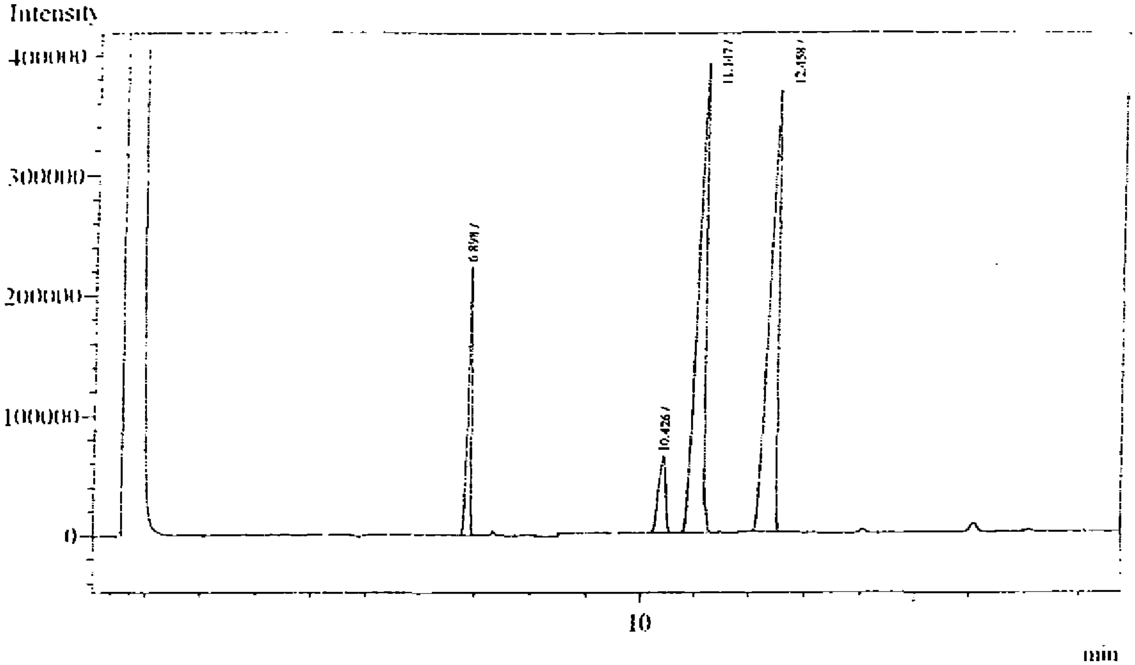
Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	7.541	183322	49846	11.293				
2	10.852	120368	22494	7.415				
3	11.494	759848	128988	46.810				
4	12.738	559723	89305	34.481				
Total		1623261	290633					

Appendix 2. Fractionation of oil T_1 (S_0B_0)



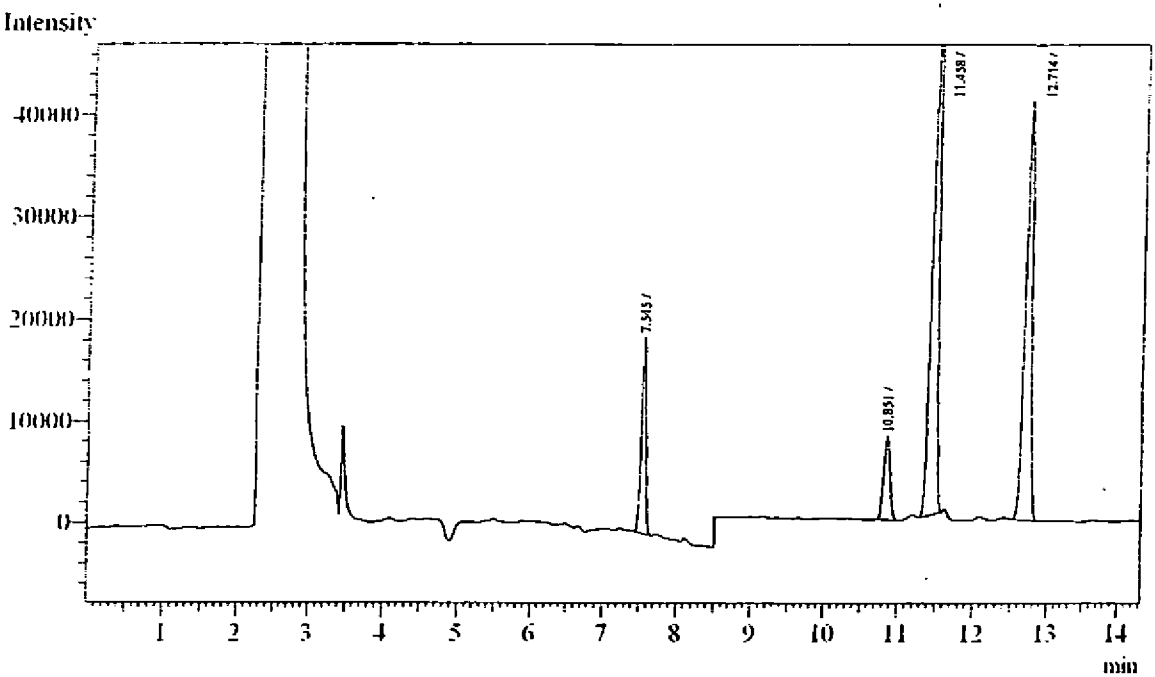
Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	7.563	581650	145531	10.350				
2	10.897	330171	45638	5.875				
3	11.594	2215379	275129	39.423				
4	12.880	2492357	280119	44.351				
Total		5619557	746417					

Appendix 3. Fractionation of oil- T_2 ($S_0B_{2.5}$)



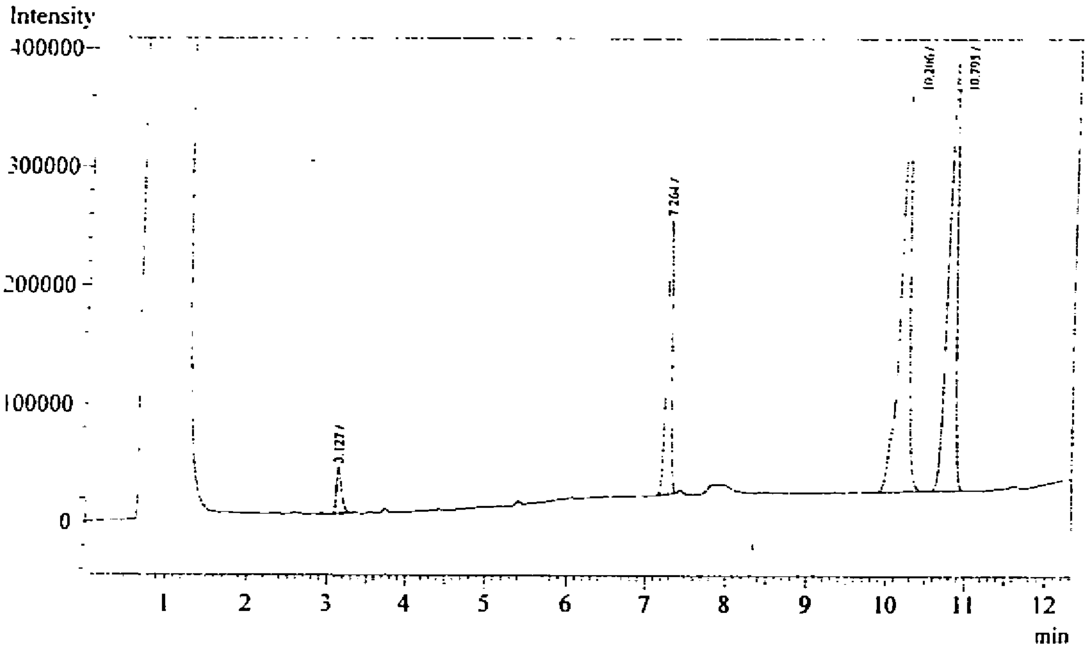
Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	6.898	943990	222735	9.873				
2	10.426	589921	63749	6.170				
3	11.147	4056872	392363	42.431				
4	12.458	3970318	369097	41.526				
Total		9561101	1047944					

Appendix 4. Fractionation of oil- T_3 ($S_0B_{5.0}$)



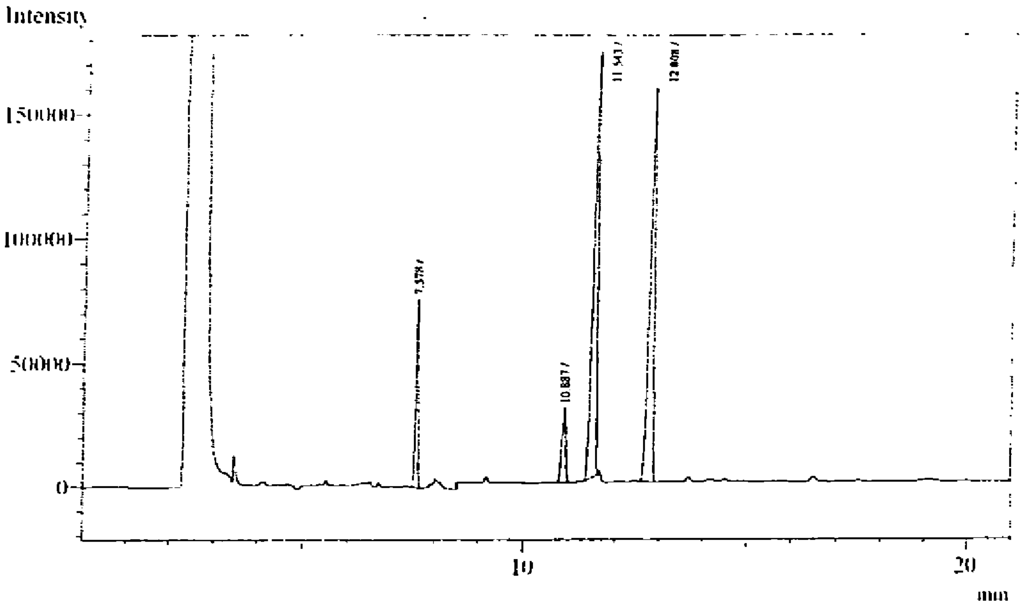
Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	7.545	82044	19150	11.946				
2	10.851	48456	8249	7.055				
3	11.458	295229	50299	42.986				
4	12.714	261078	41195	38.013				
Total		686807	118893					

Appendix 5. Fractionation of oil- T_4 ($S_0B_{7.5}$)



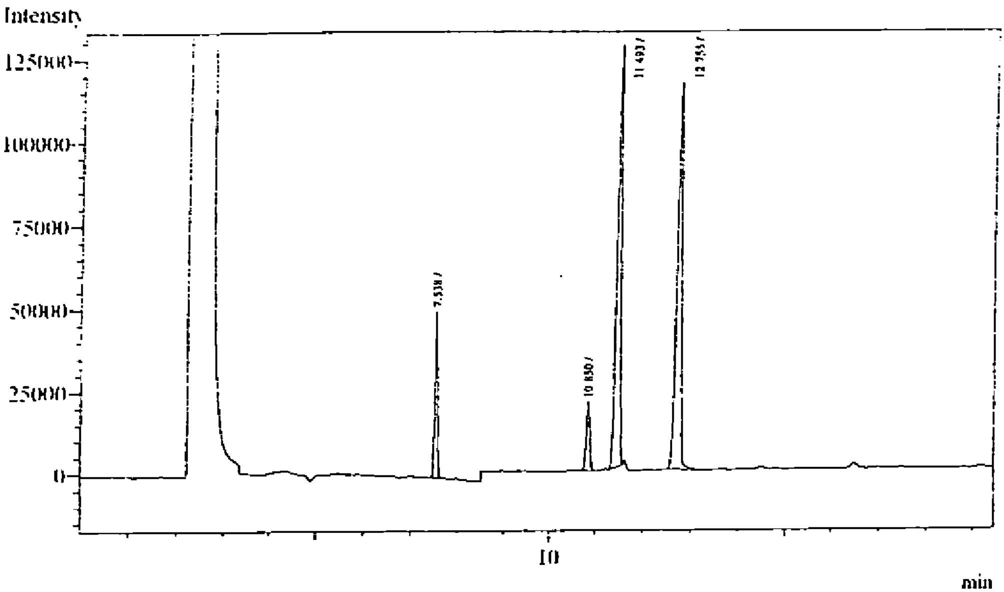
Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	3.127	176242	39467	2.591				
2	7.264	1053508	231987	15.486				
3	10.206	2854271	335854	41.957				
4	10.795	2718849	361233	39.966		V		
Total		6802870	968541					

Appendix 6. Fractionation of oil- T_5 ($S_{7.5}B_0$)



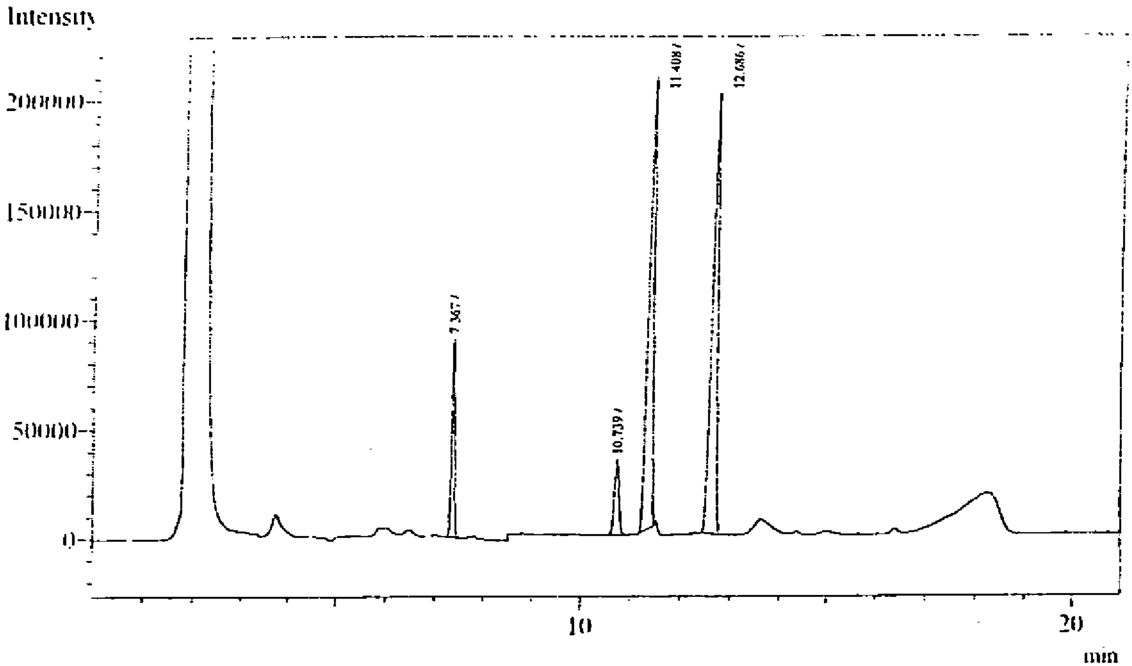
Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	7.578	285257	76119	10.632				
2	10.887	173185	30016	6.455				
3	11.543	1097719	171262	40.913				
4	12.808	1126908	159698	42.001				
Total		2683069	437095					

Appendix 7. Fractionation of oil- T_6 ($S_{7.5}B_{2.5}$)



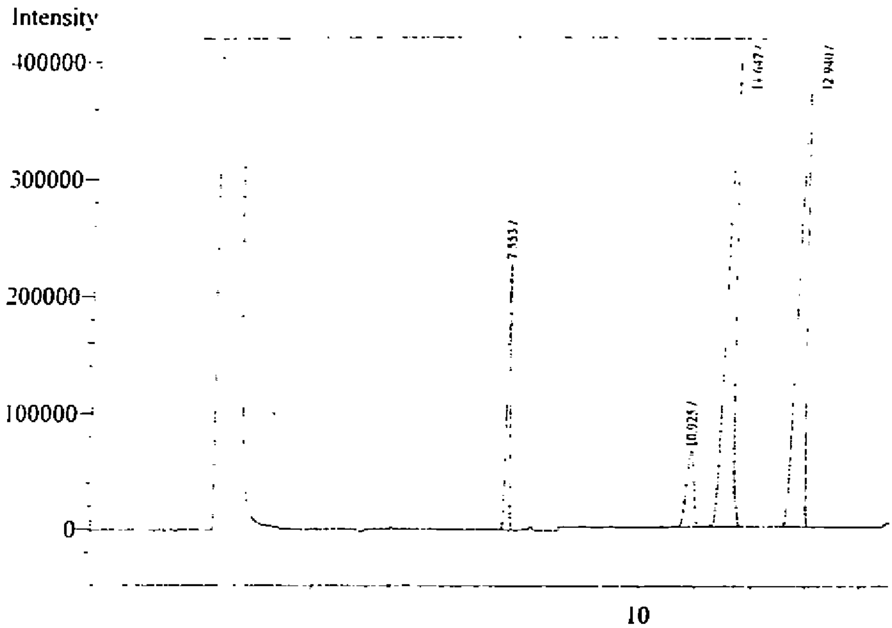
Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	7.538	186093	50331	10.049		V		
2	10.850	115832	21068	6.255				
3	11.493	761991	127129	41.146				
4	12.755	787986	116684	42.550				
Total		1851902	315212					

Appendix 8. Fractionation of oil- T_7 ($S_{7.5}B_{5.0}$)

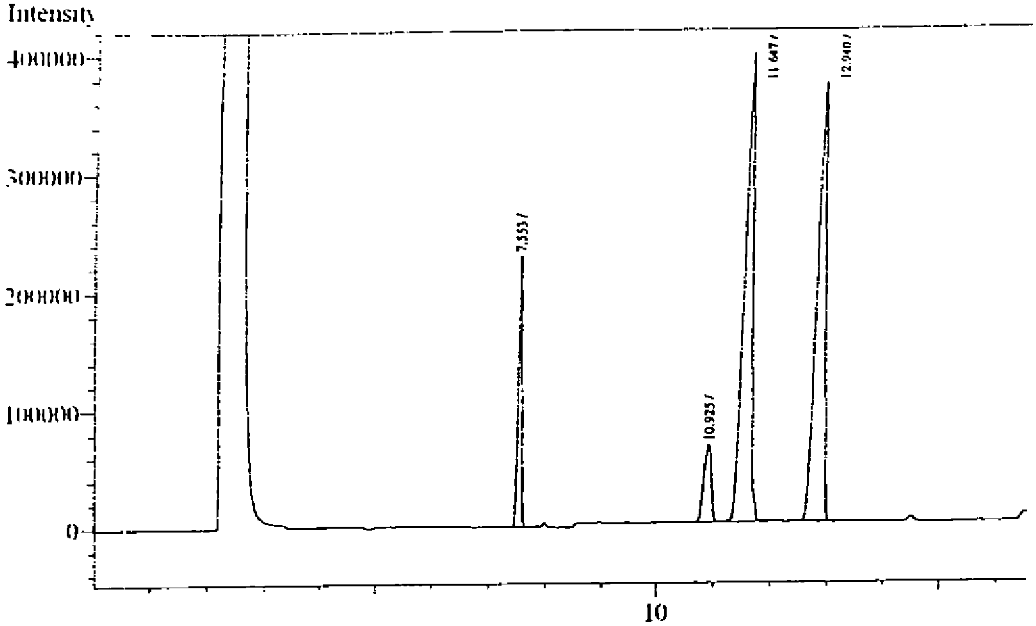


Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	7.367	361325	90739	10.188				
2	10.739	221567	34829	6.247		V		
3	11.408	1432888	205858	40.400				
4	12.686	1530947	201142	43.165		S		
Total		3546727	532568					

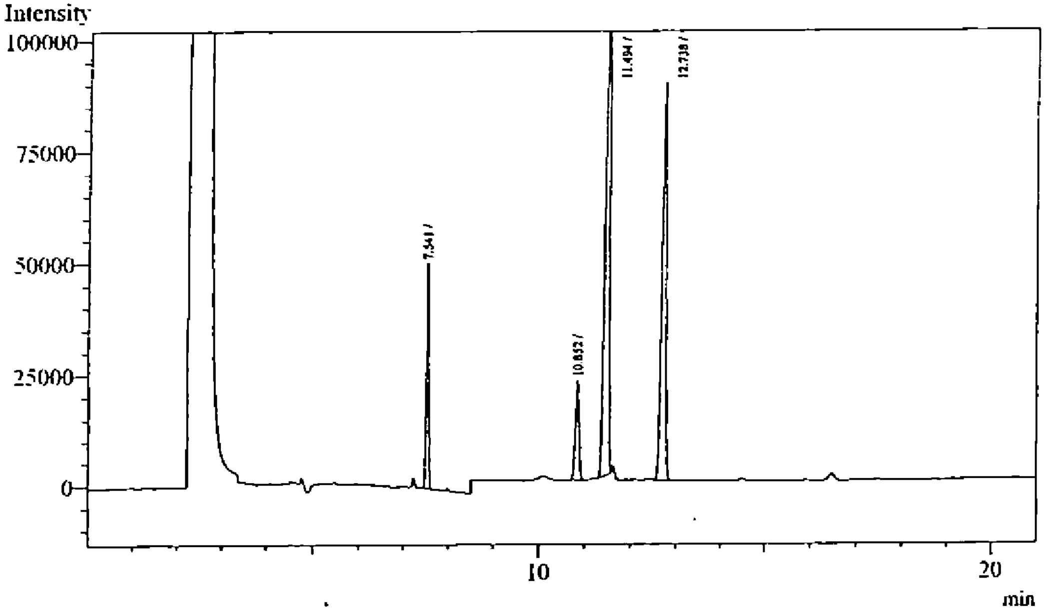
Appendix 9. Fractionation of oil- T_8 ($S_{7.5}B_{7.5}$)



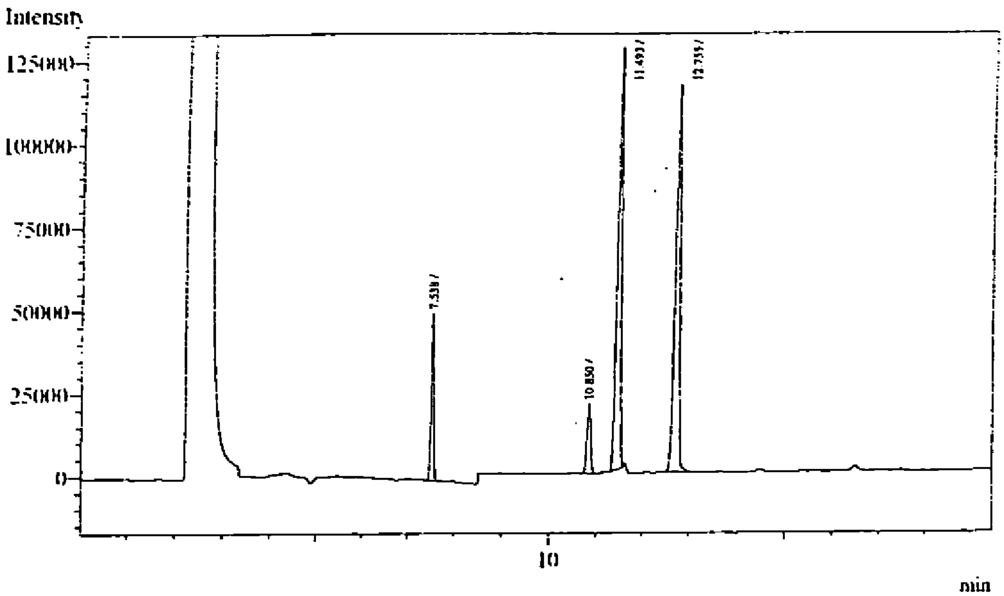
Appendix 10. Fractionation of oil T_9 ($S_{15}B_0$)



Appendix 11. Fractionation of oil T[illegible](S[illegible]B[illegible])

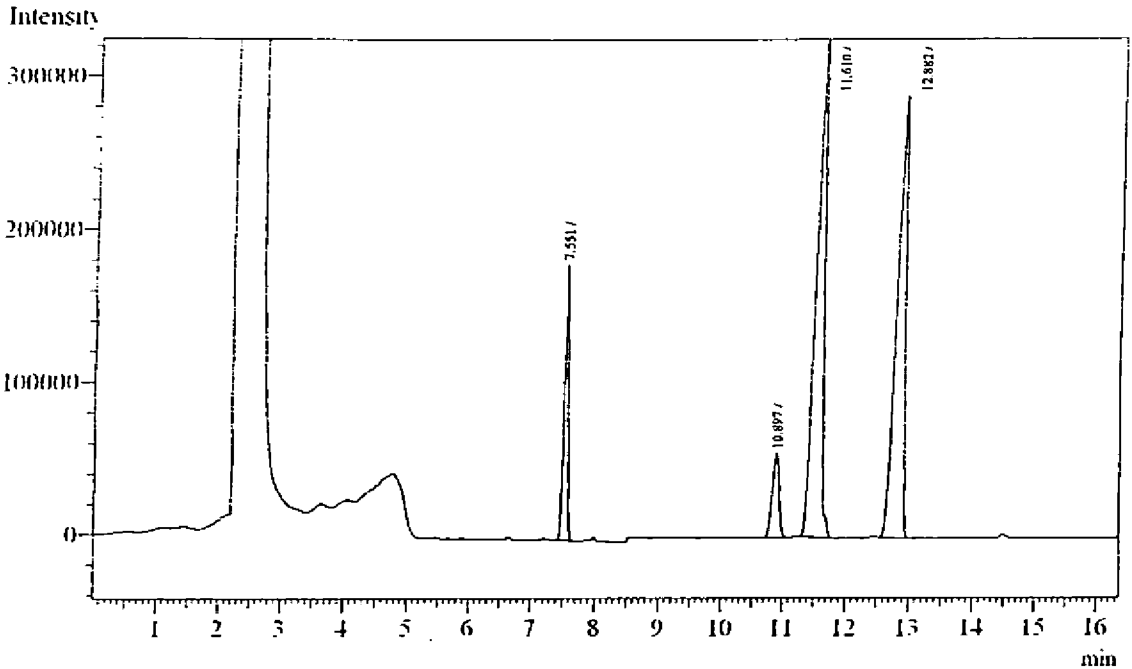


Appendix 12. Fractionation of oil T_{11} ($S_{15}B_5$)

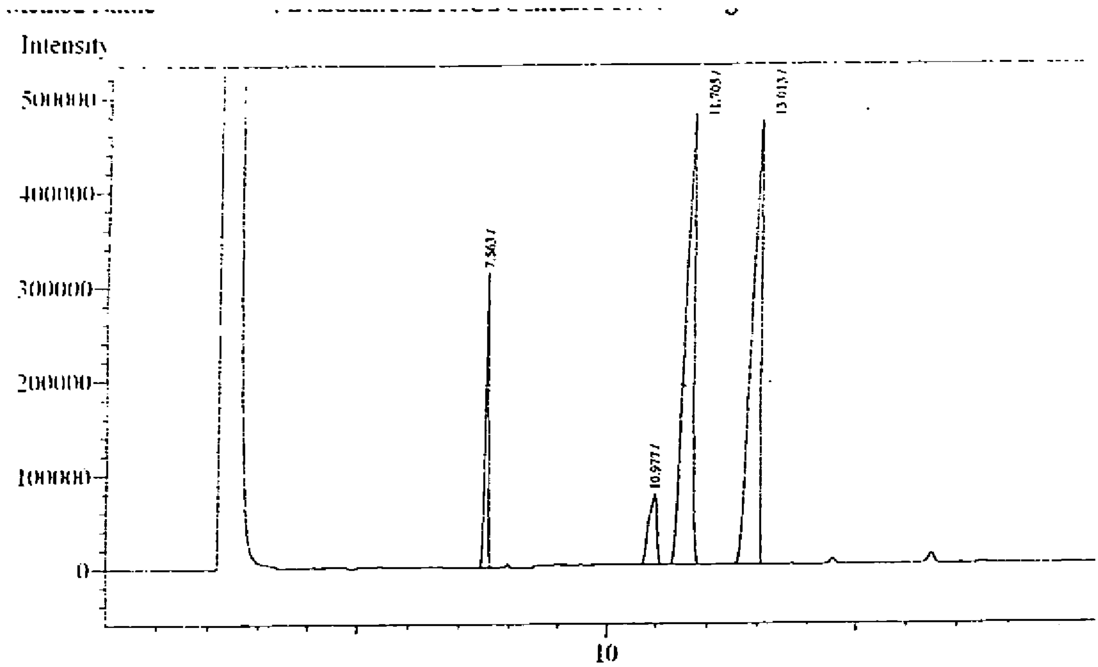


Peak#	Ret.Time	Area	Height	Conc.	Unit	Mark	ID#	Cmpd Name
1	7.538	186093	50331	10.049		V		
2	10.850	115832	21068	6.255				
3	11.493	761991	127129	41.146				
4	12.755	787986	116684	42.550				
Total		1851902	315212					

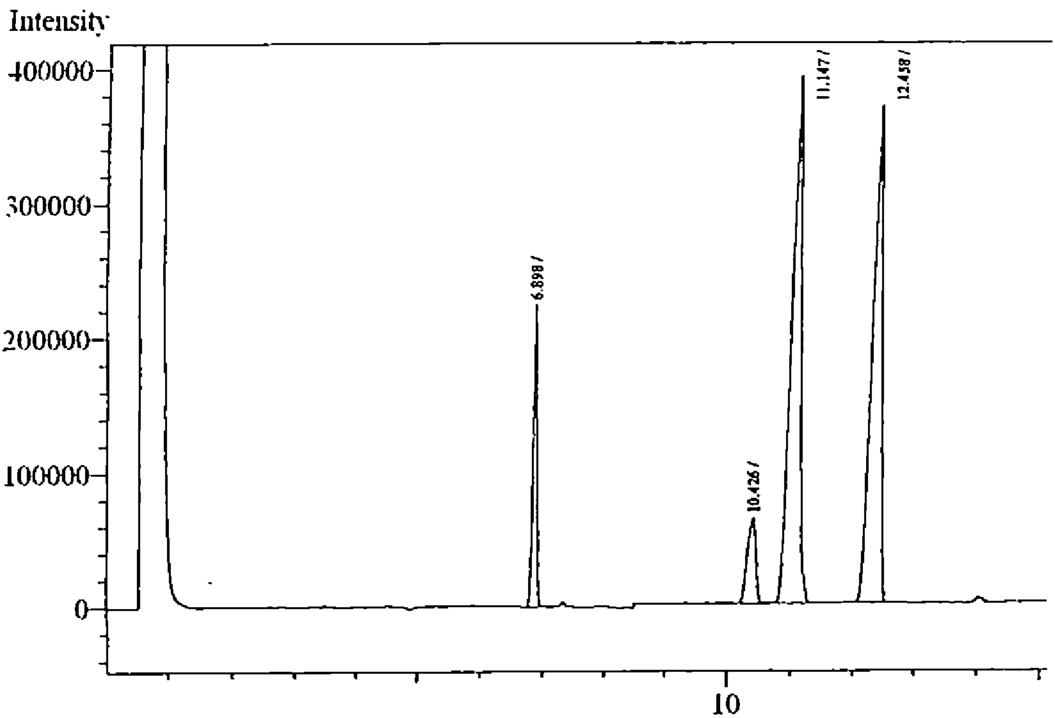
Appendix 13. Fractionation of oil $T_{1\,2}(S_{15}B_{7.5})$



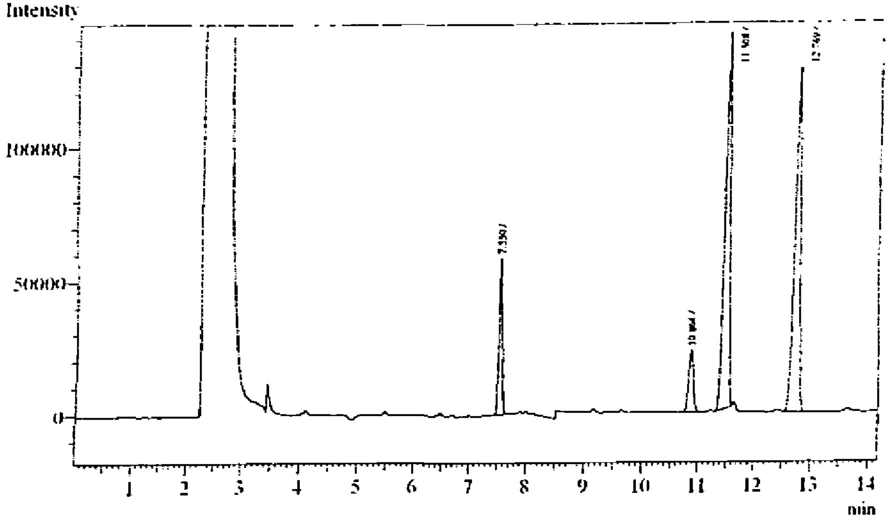
Appendix 14. Fractionation of oil T_{13} ($S_{30}B_0$)



Appendix 15. Fractionation of oil T_{14} ($S_{30}B_{2.5}$)



Appendix 16. Fractionation of oil T_{15} ($S_{30}B_5$)



Appendix 17. Fractionation of oil T_{16} ($S_{30}B_{7.5}$)