

**INFLUENCE OF SULPHUR AND BORON ON YIELD OF  
SOYBEAN (*Glycine max*) IN VERTISOLS OF KABIRDHAM  
DISTRICT**

**M. Sc. (Ag) Thesis**

**by**

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DISTRICT**

**Thesis**

**Submitted to the**

**Indira Gandhi Krishi Vishwavidyalaya, Raipur**

**by**

**Lomendra Kumar Kulhary**

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## CERTIFICATE – I

This is to certify that the thesis “**Influence of Sulphur and Boron on yield of Soybean (*Glycine max*) in Vertisols of Kabirdham District**” submitted in partial fulfilment of the requirements for the degree of “**Master of Science in Agriculture**” of the Indira Gandhi Krishi Vishwavidyalaya, Raipur, (Chhattisgarh) is a record of the bonafide research work carried out by **Lomendra Kumar Kulhary** under my guidance and supervision. The subject of the thesis has been approved by student’s advisory committee and the Director of Instructions.


No part of the thesis has been submitted for any other degree or diploma (certificate awarded etc.) or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigation have been duly acknowledged by him.

  
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## CERTIFICATE-II

This is to certify that the thesis entitled "**Influence of Sulphur and Boron on yield of Soybean (*Glycine max*) in Vertisols of Kabirdham District**" submitted by **Lomendra Kumar Kulhary** to the Indira Gandhi Krishi Vishwavidyalaya, Raipur, in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** in the Department of Soil Science & Agricultural Chemistry has been approved by the External Examiner and Student's Advisory Committee after oral examination.

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## TABLE OF CONTENTS

Chapter	Title	Page
	<b>ACKNOWLEDGEMENT</b>	iii
	<b>TABLE OF CONTENTS</b>	v
	<b>LIST OF TABLE</b>	viii
	<b>LIST OF FIGURES</b>	ix
	<b>LIST OF ABBREVIATIONS</b>	x
	<b>ABSTRACTS</b>	xi
<b>I</b>	<b>INTRODUCTION</b>	1
<b>II</b>	<b>REVIEW OF LITERATURE</b>	5
	2.1 To determine the effect of Sulphur and Boron application on growth and yield of Soybean	5
	2.2 To determine the effect of Sulphur and Boron application on uptake of Nitrogen, Phosphorus, Potassium, Sulphur and Boron by soybean	11
<b>III</b>	<b>MATERIALS AND METHOD</b>	13
	3.1 Location and experimental site	13
	3.2 Climate and weather condition	13
	3.3 Soil characteristics	13
	3.4 Cropping season	14
	3.5 Test crop	14
	3.6 Experimental details	14
	3.7 Field preparation	16
	3.8 Fertilizer application	16
	3.9 Sowing	16
	3.10 Harvesting	16
	3.11 Threshing and winnowing	16
	3.12 Observation	16
	3.12.1 Studies on crop	17
	3.12.1.1 Pre-harvest studies	17
	3.12.1.1.1 Plant height	17
	3.12.1.2 Post harvest studies	17
	3.12.1.2.1 No. of pods/plant	17
	3.12.1.2.2 Seed index	17
	3.12.1.2.3 Seed yield	17
	3.12.1.2.4 Stover yield	17
	3.12.1.2.5 Harvest index	18
	3.13 Soil and plant analysis	18
	3.13.1 Soil analysis	18

3.13.1.1	pH	18
3.13.1.2	Electrical conductivity	18
3.13.1.3	Cation exchange capacity	18
3.13.1.4	Organic Carbon	18
3.13.1.5	Available nitrogen	18
3.13.1.6	Available phosphorus	19
3.13.1.7	Available potassium	19
3.13.1.8	Available sulphur	19
3.13.1.9	Available boron	19
3.13.2	Plant analysis	20
3.13.2.1	Nitrogen content	20
3.13.2.2	Phosphorus content	20
3.13.2.3	Potassium content	20
3.13.2.4	Sulphur content	20
3.13.2.5	Boron content	21
3.13.2.6	Nutrient uptake	21
3.14	Statistical analysis	21

## **IV RESULTS AND DISCUSSION**

4.1	Growth and Yield Parameters	22
4.1.1	Plant Height (cm)	22
4.1.2	Number of Pods Plant <sup>-1</sup>	22
4.1.3	100 Seed Weight (g)	23
4.1.4	Seed Yield (q ha <sup>-1</sup> )	23
4.1.5	Stover Yield (q ha <sup>-1</sup> )	24
4.1.6	Harvest Index (%)	24
4.2	Effect of sulphur and boron on nutrient content of soybean	28
4.2.1	Nitrogen Content (%)	28
4.2.2	Phosphorus Content (%)	28
4.2.3	Potassium Content (%)	28
4.2.4	Sulphur Content (%)	30
4.2.5	Boron Content (mg kg <sup>-1</sup> )	30
4.3	Effect of sulphur and boron on nutrient uptake by soybean	30
4.3.1	Nitrogen Uptake (kg ha <sup>-1</sup> )	30
4.3.2	Phosphorus Uptake (kg ha <sup>-1</sup> )	34
4.3.3	Potassium Uptake (kg ha <sup>-1</sup> )	34
4.3.4	Sulphur Uptake (kg ha <sup>-1</sup> )	35
4.3.5	Boron Uptake (g ha <sup>-1</sup> )	35
4.4	Effect of sulphur and boron on available nutrient status of post harvest soil	39
4.4.1	Available nitrogen (kg ha <sup>-1</sup> )	39
4.4.2	Available Phosphorus (kg ha <sup>-1</sup> )	39
4.4.3	Available Potassium (kg ha <sup>-1</sup> )	40
4.4.4	Available sulphur (kg ha <sup>-1</sup> )	40
4.4.5	Available boron (mg ha <sup>-1</sup> )	41

<b>V</b>	<b>SUMMARY AND CONCLUSIONS</b>	45
	<b>REFERENCES</b>	51
	<b>APPENDICES</b>	58
	Appendix A	58
	<b>VITA</b>	59

---

## LIST OF TABLES

---

<b>Table</b>	<b>Title</b>	<b>Page</b>
3.1	Physico-chemical properties of soil of experiment	14
3.2	Treatments details	15
4.1	Effect of sulphur and boron on growth, yield attributes and yield of soybean	26
4.2	Effect of sulphur and boron application on nutrient content in seed and stover of soybean	29
4.3	Effect of sulphur and boron application on nutrient uptake by seed & stover of soybean	31
4.4	Effect of sulphur and boron application on nutrient uptake by seed & stover of soybean	37
4.5	Effect of sulphur and boron on available nutrient status of post harvest soil	42

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## LIST OF FIGURES

---

<b>Figure</b>	<b>Title</b>	<b>Page</b>
4.1	Effect of sulphur and boron on growth, yield attributes and yield of soybean	26
4.2	Effect of sulphur and boron on nitrogen uptake (kg ha <sup>-1</sup> )	29
4.3	Effect of sulphur and boron on Phosphorus uptake (kg ha <sup>-1</sup> )	31
4.4	Effect of sulphur and boron on Potassium uptake (kg ha <sup>-1</sup> )	37
4.5	Effect of sulphur and boron on Sulphur uptake (kg ha <sup>-1</sup> )	42
4.6	Effect of sulphur and boron on Boron uptake (g ha <sup>-1</sup> )	37
4.7	Effect of sulphur and boron on available nitrogen (kg ha <sup>-1</sup> )	43
4.8	Effect of sulphur and boron on available phosphorus (kg ha <sup>-1</sup> )	43
4.9	Effect of sulphur and boron on available potassium (kg ha <sup>-1</sup> )	44
4.10	Effect of sulphur and boron on available sulphur (kg ha <sup>-1</sup> )	44
4.11	Effect of sulphur and boron on available Boron (mg ha <sup>-1</sup> )	44

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## LIST OF ABBREVIATIONS

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@	At the rate of
%	Per cent
oC	Degree Celsius
B	Boron
CG	Chhattisgarh
Cm	Centimeter
EC	Electrical Conductivity
<i>et al.</i>	and co-worker/and others
Fig.	Figure
FYM	Farm yard manure
g	Gram
ha	hectare
<i>i.e.</i>	That is
K	Potassium
kg	Kilogram
m	Meter
mm	milimeter
Mt	Million tonne
N	Nitrogen
OC	Organic carbon
P	Phosphorus
pH	Logarithm of the reciprocal of the H <sup>+</sup> ion activity
ppm	Parts per million
q	Quintal
RDF	Recommended dose of fertilizer
RDN	Recommended dose of nitrogen
RH	Relative humidity
S	Sulphur
S. No	Serial number
t	Tonne
<i>Viz</i>	That is to say / in other words
Wt.	Weight
Zn	Zinc

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## THESIS ABSTRACT

---

Title of the Thesis : Influence of Sulphur and Boron on yield of Soybean (*Glycine max*) in Vertisols of Kabirdham District.


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Degree to be awarded : M. Sc. (Ag), Soil science and agricultural chemistry

  
Signature of Major Advisor

  
Signature of the student

  
Signature of Head of Department

---

## ABSTRACT

The present investigation was carried out to determine the effect of sulphur and boron application on growth and yield of soybean, uptake of nitrogen, phosphorus, potassium, sulphur and boron by soybean and available nutrient status on post harvest soil. Experiment comprises four levels of sulphur viz., 0, 15, 30 and 45 kg ha<sup>-1</sup> and four levels of boron viz., 0, 0.5, 1.0 and 1.5 kg ha<sup>-1</sup>. Yield attributes and yield of soybean was significantly influenced by different sulphur levels and maximum yield (21.04 kg ha<sup>-1</sup> seed yield and 22.77 kg ha<sup>-1</sup> stover yield) was observed with 30 kg S ha<sup>-1</sup> and it was closely followed by 45 kg S ha<sup>-1</sup> (19.67 kg ha<sup>-1</sup> seed yield and 22.20 kg ha<sup>-1</sup> stover yield) but were statistically at par with each other. Among boron levels, 1.0 kg B ha<sup>-1</sup> was superior to others for getting maximum soybean yield (18.82 kg ha<sup>-1</sup> seed yield and 21.05 kg ha<sup>-1</sup> stover yield). Sulphur and boron application resulted in increased nutrient uptake by soybean. Maximum nitrogen, phosphorus, potassium, sulphur and boron uptake (147.03, 10.17, 39.61, 8.35 kg ha<sup>-1</sup> and

phosphorus, potassium, sulphur and boron uptake (147.03, 10.17, 39.61, 8.35 kg ha<sup>-1</sup> and 98.71 g ha<sup>-1</sup> respectively) was observed with 30 kg S ha<sup>-1</sup>. Maximum uptake of nitrogen, phosphorus, potassium, sulphur and boron (131.51, 9.10, 36.85, 7.74 kg ha<sup>-1</sup> and 89.38 g ha<sup>-1</sup> respectively) was associated with application of 1.0 kg B ha<sup>-1</sup>. Available nitrogen, phosphorus and potassium in post harvest soil were found higher with application of 30 kg S ha<sup>-1</sup> and 1.0 kg B ha<sup>-1</sup>. However, available sulphur was more in treatment where sulphur was applied at higher level (45 kg S ha<sup>-1</sup>) and similarly available boron was found more where higher level of boron was applied (1.5 kg B ha<sup>-1</sup>). Interaction of sulphur and boron levels had no significant effect on different parameters under study.

## शोध सारांश

### कबीरधाम जिले के वर्टीसॉल (कन्हार मृदा) में सोयाबीन की उपज पर सल्फर और बोरान का प्रभाव

वर्तमान परीक्षण के बाद फसल की मृदा पर सोयाबीन और उपलब्ध पोषक तत्वों की स्थिति के आधार पर सोयाबीन की बढ़वार और पैदावार, नत्रजन, स्फुर, पोटाश, सल्फर और बोरान प्रभाव पर, सल्फर और बोरान के प्रयोग के प्रभाव को निर्धारित करने के लिये किया गया था। सल्फर प्रयोग के चार स्तर 0, 15, 30, और 45 किलोग्राम प्रति हेक्टेयर तथा बोरान प्रयोग के चार स्तर 0, 0.5, 1.0 और 1.5 किलोग्राम प्रति हेक्टेयर था। सोयाबीन की उपज गुणवक्ता और पैदावार अलग-अलग सल्फर स्तरों से प्रभावित था और अधिकतम उपज (21.04 किलोग्राम प्रति हेक्टेयर बीज उपज और 22.55 किलो प्रति हेक्टेयर पुआल) 30 किलो सल्फर के साथ पाया गया। जबकि यह उपज (19.67 किलोग्राम बीज उपज प्रति हेक्टेयर और 22.20 किलो प्रति हेक्टेयर पुआल) 45 किलोग्राम सल्फर के करीब पाया गया था। लेकिन यह दोनों प्रयोग सांख्यिकीय रूप से समान थे।

बोरान स्तर के बीच, अधिकतम सोयाबीन उपज प्राप्त करने के लिये अन्य स्तरों में से 1.0 किलोग्राम बोरान सबसे अधिक बेहतर था। सल्फर एवं बोरान के प्रयोग से सोयाबीन के द्वारा पोषक तत्वों का उदग्रहण में अधिक वृद्धि हुई। अधिकतम नत्रजन, स्फुर, पोटाश, सल्फर, और बोरान का उदग्रहण (क्रमशः 197.03, 10.17, 39.61, 8.35 किलोग्राम प्रति हेक्टेयर और 98.71 ग्राम प्रति हेक्टेयर) 30 किलोग्राम प्रति हेक्टेयर सल्फर के साथ पाया गया। एन पी के सल्फर और बोरान का अधिकतम उदग्रहण (क्रमशः 131.51, 9.10, 36.85, 7.74 किलोग्राम प्रति हेक्टेयर और 89.38 ग्राम प्रति हेक्टेयर) 1.0 किलोग्राम बोरान के साथ पाया गया। फसल कटाई के बाद मिट्टी में उपलब्ध नत्रजन, स्फुर, पोटाश, 30 किलोग्राम सल्फर और 1.0 किलोग्राम बोरान प्रति हेक्टेयर के प्रयोग के साथ अधिकतम पाया गया।

हांलांकि, उपलब्ध सल्फर वहाँ ज्यादा पाया गया जहाँ पर अधिक सल्फर का अधिक स्तर बढ़ाया गया था (45 किलोग्राम सल्फर प्रति हेक्टेयर) और इसी तरह उपलब्ध बोरान की मात्रा भी अधिक स्तर पर पाया गया (1.5 किलोग्राम बोरान प्रति हेक्टेयर)। सल्फर और बोरान स्तर का विश्लेषण के दौरान विभिन्न मापदण्डों पर कोई महत्वपूर्ण प्रभाव नहीं पड़ा।

## CHAPTER- I INTRODUCTION

---

Soybean designated as 'miracle bean' has established its potential as an industrially vital and viable oilseed crop in many areas of India. It is a cheapest source of vegetable oil and protein. It contains about 40% protein, well balanced in essential amino acids, 20% oil rich with poly unsaturated fatty acids specially Omega 6 and Omega 3 fatty acids, 6-7% total mineral, 5-6% - area of 12.2 m ha, with production potential of 11.95 million tonnes and average productivity of 979.3 kg ha<sup>-1</sup> (Anon., 2013<sub>a</sub>). The productivity of soybean is less in India as compared to world average (2484.1 kg ha<sup>-1</sup>). Global area and production of soybean is 111.27 m ha and 276.4 million tonnes respectively (Anon., 2013<sub>b</sub>). The major soybean producing states in India are Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh and Karnataka (Anon., 2013).

The imbalanced and inadequate nutrition is found to be one of the major limiting factors for its poor yield. Among the major nutrients, sulphur is found to be quite important now a day in many soybean-growing areas. It is the 13th most abundant element in the earth crust with an average concentration of 0.06%. It is now considered as the 4th major plant nutrient after nitrogen (N), phosphorous (P) and potassium (K) (Patel *et al.*, 2013<sub>a</sub>). Sulphur is an important part of every living cell, required for the formation of chlorophyll and for the activity of ATP-sulphurylase (the enzyme involved in sulphur metabolism). It is involved in several important physiological functions in soybean including oil synthesis and acts as precursor for many amino acids, namely cysteine (26%S), cystine (27%S) and methionine (21%S) which act as building blocks for the synthesis of protein (Patel *et al.*, 2013<sub>b</sub>). The yield attributing characters of crops were greatly affected by sulphur application (Choudhary *et al.*, 2014).

As soybean is rich in both oil and protein, the requirement of sulphur is quite high. Over the years due to intensive cultivation and use of sulphur free fertilizers, the deficiency of sulphur has begun to appear and it is slowly becoming a major constraint for realizing higher yield in soybean. Sulphur deficiencies are

now widespread in Indian soil and reports of more areas found deficient in S are coming in regularly. In the early 1990s, S deficiencies in Indian soils were estimated to occur in about 130 districts (Tandon, 1991). Recently, soil fertility survey by the Indian Council of Agricultural Research (ICAR) based on the analysis of 47,000 soil samples have shown S deficiencies to be a widespread problem. Besides sulphur, boron is another element, which is highly important in the physiological functions in soybean. Boron's widespread role within the plant includes cell wall synthesis, sugar transport, cell division, differentiation, membrane functioning, root elongation, and regulation of plant hormone levels (Pilbam and Kirkby, 1983; Romheld and Marschner, 1991; Marschner, 1995).

Sulphur play an outstanding role in formation of Sulphur containing compounds is concerned. Important role of Sulphur in plant metabolism which involved in synthesis of glucosides and proteins that promotes nodule formation, chlorophyll and oil. The increase in seed yield of soybean by S treatment can be related to increase in growth and yield characteristics (plant height, pods plant<sup>-1</sup> etc.) as well as stimulatory effect of applied S in the synthesis of chloroplast protein resulting in greater photosynthetic activity by the crop, which in turn increased the yield (Biswas and Tewatia, 1992). In addition, S has an important role in improving soil reaction. When added into the soil, sulphur is converted to sulphuric acid by sulphur-oxidizing micro-organisms and lowers soil pH (locally) resulting in stabilized nutrient elements.

Boron is one of the essential plant nutrients. Boron having a marked effect on plant from the stand point of both nutrition as well as toxicity (Das, 2003). The range between the level of soil boron resulting in deficiency and that causing toxicity in plant is relatively small. The critical limit of boron in plant refers to a level at or below which plant either develops deficiency symptoms or causes statistically significant or 5 to 10% reduction in crop yield as compared to optimum (Debnath and Ghosh, 2011).

Boron has particularly attended an important position in intensive agriculture. Boron is required for the proper development of growing tips, phloem and xylem. Boron helps in germination and growth of pollen grains and also development of pollen-tube thus facilitating fertilization in plant and grain yield

(Shankhe *et al.*, 2004). Boron regulates the transport of sugars through plant cell membranes, the rate of cell development, cell division, and the synthesis of proteins. Deficiency symptoms of the plant are first noticed at the terminal growing points: new leaves, flower buds, stem tips.

In Chhattisgarh, agriculture is mainly based on rainwater; therefore most of the crops are grown as rainfed in *kharif* season. Soybean occupies 1.52 lac hectares in Chhattisgarh with a productivity of 11.54 q ha<sup>-1</sup>. More acreage of soybean in Chhattisgarh state is in plain area namely Durg, Bemetara, Rajnandgaon, Mungeli and Kabirdham districts. In Kabirdham district soybean is grown in 44.25 thousand hectare area with a productivity of 12.10 q ha<sup>-1</sup>. Though the soybean productivity of the district is higher than the average productivity of Chhattisgarh state, there is still scope of productivity enhancement. Productivity can be enhanced by growing improved varieties and by following proper agronomic and nutrient management practices. Among the fertilizer elements, sulphur requirement of oilseed crops is quite high as compared to other crops (Das and Das, 1994). Oil seed crops respond to liberal application of sulphur. Sulphur is involved in the synthesis of fatty acids and also increases protein quality through the synthesis of certain amino acids such as cystine, cystein and methionine (Havlin *et al.*, 1999). It is increasingly being recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium. Boron is an essential micronutrient for plants. Among micro-nutrients, boron has found a wider use for agronomic and horticultural crops. Boron is associated with calcium utilization, cell division, flowering and fruiting, water relations, and protein synthesis (Berger, 1949; Malewar *et al.*, 2001). The fertility status of soils has been declining continuously due to non-judicious use of chemical fertilizers and intensive cropping without proper replenishment of nutrients and organic matter. Consequently, in addition to N, P and K deficiencies, deficiencies of some other nutrients such as S, Zn and B are being observed in many parts of the country (Vaiyapuri *et al.*, 2010). Many research works have been done on the effect of N, P and K fertilizers on the yield of soybean crop. But, a few works have been carried out on the effect of sulphur and boron on yield of soybean, although it has been experimentally proved in different parts of the

country as well as in many parts of the world that sulphur is much essential to increase the production of soybean.

In view of this, it may be worthwhile to evaluate the **“Influence of Sulphur and Boron on yield of Soybean (*Glycine max*) in Vertisols of Kabirdham District”** with the following objectives:

1. To determine the effect of Sulphur and Boron application on growth and yield of Soybean.
2. To determine the effect of Sulphur and Boron application on uptake of Nitrogen, Phosphorus, Potassium, Sulphur and Boron by soybean.

## CHAPTER-II REVIEW OF LITERATURE

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This chapter deals review of various experimental finding of different research workers covering important aspects on effect of Influence of Sulphur and Boron on yield of Soybean (*Glycine max*) in *Vertisols* of Kabirdham District (C.G.) are presented under following heads.

2.1 To determine the effect of Sulphur and Boron application on growth and yield of Soybean.

2.2 To determine the effect of Sulphur and Boron application on uptake of Nitrogen, Phosphorus, Potassium, Sulphur and Boron by soybean.

### **2.1 To determine the effect of Sulphur and Boron application on growth and yield of Soybean**

Aulakh *et al.* (1990) observed that the combined application of P and S shows a synergistic effect up to 35 kg P ha<sup>-1</sup> and 40 kg S ha<sup>-1</sup>. The balanced P-S fertilization resulted in maximum seed yield and enhanced the process of protein and oil synthesis.

Abbes *et al.* (1992) conducted an experiment in greenhouse and field trials found that the highest dry matter and pod weight were obtained with the combined application of 120 kg S and 90 kg N ha<sup>-1</sup> to Soybean crop.

Sharma *et al.* (1992) observed that the highest average pod yield was obtained with application of gypsum (2.97 t ha<sup>-1</sup>) followed by FeSO<sub>4</sub> (2.81 t ha<sup>-1</sup>) in groundnut.

Mahapatra and Jee (1992) observed that application of S @ 20 kg ha<sup>-1</sup> resulted in significantly higher seed yield, seed siliquae<sup>-1</sup>, siliquae plant<sup>-1</sup> as compared with those of other lower levels. The seed yields with S application @ 20 and 25 kg ha<sup>-1</sup> were at par. Oil and protein contents were also influenced favourably by S application upto 20 kg ha<sup>-1</sup>.

Sreemannarayana and Sreenivasa Raju (1993) reported that application of 60 kg S ha<sup>-1</sup> to sunflower gave highest seed yield (1.48 t ha<sup>-1</sup>) and soil available S increased with increasing S application and crop age. The S utilization at maturity stage decreased with increased S fertilization up to 60 kg S ha<sup>-1</sup>. Further, they observed that on the *Alfisols*, dry matter yield increased up to 60 kg S ha<sup>-1</sup>, whereas 26 on the *Vertisols*, the increase in yield was recorded only up to 40 kg S ha<sup>-1</sup>.

Rerkasem *et al.* (1997) investigated the relationship of seed B concentration to seed germination, seedling normality, and plant growth of soybean (*Glycine max*) sown in soil with a range of B levels. Increasing soil B had no effect on germination but decreased the percentage of abnormal seedlings by one third. Seed with 10 mg B kg<sup>-1</sup> germinated as well as seed with 14 or 20 mg B ha<sup>-1</sup>, but when sown on a low B soil, 80% of the seedlings were abnormal compared with 50 and 20%, respectively. Increasing soil B almost eliminated the incidence of seedling abnormality when seed contained 10 - 20 mg B ha<sup>-1</sup>. When grown to maturity on the lowest soil B, plants from seed with 10 mg B ha<sup>-1</sup> produced less than half the seed yield of plants from seed with 14 or 20 mg B ha<sup>-1</sup>. They had fewer pods per plant and fewer seeds per pod. They responded strongly to increasing soil B, so that in soil with higher B levels, plants from seed with 10, 14 or 20 mg B ha<sup>-1</sup> gave the same yield.

Jaggi and Sharma (1999) conducted a pot experiment to study the response of S applied @ 0, 30 and 60 ppm in raya using 13 different soils of Kangra district of Himachal Pradesh and found a consistent significant increase in dry matter yield, S uptake and a decrease in flowering period (advanced maturity) with 30 and 60 application. Advancement in maturity by 2-4, and 4-11 days was recorded with application of 30 and 60 ppm sulphur, respectively.

Mohanti *et al.* (2000) evaluated the effects of different levels of S (0, 10, 20 and 30 kg ha<sup>-1</sup>) and B (0 and 0.002% at pre-flowering or pre-podding) on soybean. S at 30 kg ha<sup>-1</sup> recorded the highest values for these parameters. B and its interaction with S had no significant effect. Net realization per investment was highest with S at 20 kg ha<sup>-1</sup> (1.18), followed by S at 30 kg ha<sup>-1</sup> (1.09).

Singh *et al.* (2003) determined the optimum level of S (0, 20, 40 and 60 kg ha<sup>-1</sup>) and B (0, 0.5, 1.0 and 2.0 kg ha<sup>-1</sup>) for soybean grown in an acidic upland soil.

The stover yields of soybean were significantly influenced by graded levels of S and B application. The crop yield increased more due to S compared to B application. The S x B treatment revealed that maximum seed yield was obtained with 60 kg S + 2.0 kg B ha<sup>-1</sup>.

Biswas *et al.* (2003) studied the growth and yield of soybean in relation to different levels of added sulphur and molybdenum. The results indicated that single and combined effect of different levels of sulphur and molybdenum had significant effect on growth and yield of soybean. Biological yield attributes viz., leaf area; leaf chlorophyll and total sugar content of soybean leaf were also significantly affected by the application of different levels of sulphur and molybdenum. The highest number of effective pod plant<sup>-1</sup>, pod length, grain and stover yield and harvest index were found by the application of 12 kg S ha<sup>-1</sup>. The maximum number of effective pod plant<sup>-1</sup>, grain and stover yield and harvest index were obtained by the application of 2 kg Mo ha<sup>-1</sup> and the lowest from the control.

Yadav *et al.* (2004) studied on the effect of varying levels of sulphur (S<sub>0</sub>, S<sub>20</sub>, S<sub>40</sub> and S<sub>60</sub> kg ha<sup>-1</sup>) as gypsum and source of bio-fertilizer @ 200 g/10 kg of seed inoculated B<sub>1</sub> (Azotobacter) on yield of mustard crop and soil properties. The grain yield (q ha<sup>-1</sup>) was significantly increased by the application of both sulphur and source of biofertilizer. The maximum yield was obtained by the sulphur application @ 40 kg ha<sup>-1</sup> and by the source of biofertilizer (B<sub>1</sub>) @ Azotobacter/10 kg seed inoculate. The interaction between sulphur and biofertilizer was significant and the maximum increase in yield was obtained by applied sulphur @ 40 kg ha<sup>-1</sup> at biofertilizer (B<sub>0</sub>B<sub>1</sub>) 0 and 200 g Azototobacter/10 kg seed inoculate.

Hosmath *et al.* (2006) initialled a field experiment ant found that the soil was deficient in sulphur (<10 mg ha<sup>-1</sup>). Further they observed the soybean seed yield was significantly increased with the application of sulphur @ 20 kg ha<sup>-1</sup> (2534 kg ha<sup>-1</sup>) compared to sulphur levels; 30 kg ha<sup>-1</sup> (2494 kg ha<sup>-1</sup>), 40 kg ha<sup>-1</sup> (2376 kg ha<sup>-1</sup>) and 10 kg ha<sup>-1</sup> (2226 kg ha<sup>-1</sup>).

Sounda *et al.* (2006) evaluated the effects of S and B fertilization on yield, quality and nutrient uptake by soybean crop under upland condition and found that the highest yield and yield attributes were obtained with the application of sulphur @ 30 kg S ha<sup>-1</sup> and 1.5 kg B ha<sup>-1</sup>. S and B uptake as well as protein and oil

contents of soybean grain were significantly influenced by sulphur and boron fertilization. The B:C ratio was highest with the application of 30 kg S ha<sup>-1</sup> and 1.5 kg B ha<sup>-1</sup>. The overall results suggested that application of S @ 30 kg ha<sup>-1</sup> and B @ 1.5 kg ha<sup>-1</sup> proved to be the best for producing high yield of good quality grain of soybean.

Vyas, Rupendra & Khandwe (2008) studied the effect of sulphur and boron levels on physiological parameters, productivity, soil fertility and economics of soybean under rainfed conditions. Progressive increase in sulphur and boron levels increased crop growth rate, total chlorophyll content, pods per plant and seed yield. But significant response of sulphur application was obtained up to 20 kg ha<sup>-1</sup> and it gave CGR (10.94 g/m<sup>2</sup>/day), total chlorophyll content (2.55 mg/g/fresh weight), number of pods per plant (24.19), harvest index (42.91%), and seed yield (2059 kg ha<sup>-1</sup>), being 33.74, 13.33, 9.35, 4.92 and 12.14 per cent higher, and respectively over the control. The crop responded up to 0.5 kg boron ha<sup>-1</sup> which increased the pods per plant by 7.04 and seed yield by 6.33 per cent over non application of boron. CGR and total chlorophyll content were found significantly superior at 1.5 kg B ha<sup>-1</sup>. The uptake of sulphur in seed (6.82 kg ha<sup>-1</sup>) and straw (4.8 kg ha<sup>-1</sup>) was significantly higher up to 10 kg S ha<sup>-1</sup>. The significant higher value of oil was obtained at 10 kg S ha<sup>-1</sup> and 0.5 kg B ha<sup>-1</sup> whereas, protein was significantly higher at 30 kg S ha<sup>-1</sup> and 2.0 kg B ha<sup>-1</sup>. The interaction effect between sulphur and boron in all the parameters was not significant.

Vaiyapuri *et al.* (2008) studied the effect of sulphur and boron fertilization on yield, uptake of sulphur, boron and protein content of soybean. The results of the experiments revealed that sulphur and boron uptake of grains showed a significant variation due to the application of different levels of sulphur and boron. The highest S and B uptake, yield and protein content were found with application of sulphur @ 30 kg ha<sup>-1</sup> and boron @ 1.0 kg ha<sup>-1</sup>.

Singh *et al.* (2008) studied the effect of sulphur and boron fertilization on yield attributes and yield of soybean and observed The results of the experiments revealed that application of 30 kg S ha<sup>-1</sup> recorded better yield attributes viz., branches plant<sup>-1</sup>, pods plant<sup>-1</sup>, seeds pod<sup>-1</sup> and 100-seed weight and higher yield than the other treatments. Similarly, application of boron at 1.0 kg ha<sup>-1</sup> recorded better

yield attributes and higher yield of grain and straw.

Layek *et al.* (2008) studied the effect of levels of sulphur (S) and boron (B) individually and in combination on the performance of soybean. There was significant effect of levels of S and B on the performance of soybean. Application of S upto 30 kg recorded significantly higher growth parameters viz. plant height<sup>-1</sup>, number of branches, leaf area index etc. and yield attributes viz. number of pods plant<sup>-1</sup>, seed pod<sup>-1</sup>, seed index etc. and yield of soybean as compared to lower levels of S. Similarly application of B @ 1.0 kg recorded significantly higher growth parameters. Further increase in the levels of S and B did not improve the parameters significantly. The combined application of 30 kg S and 1.0 kg B too recorded significant interaction effect on many of the growth and yield attributes and yield of soybean.

Meena (2008) conducted a field experiment during kharif on *Vertisols* to find out the effect of different levels of sulphur (0, 10, 20, 30 and 40 kg ha<sup>-1</sup>) and boron (0.0, 0.5, 1.0, 1.5 and 2.0 kg ha<sup>-1</sup>) on productivity, quality and profitability of soybean. And found that soybean responded significantly to the application of sulphur (S) and boron (B). Among the S levels, 30 kg per ha increased the number of branches plant<sup>-1</sup>, pods plant<sup>-1</sup> and seeds pod<sup>-1</sup> by 29, 23.9 and 11.6 per cent respectively and produced 16.1 per cent higher seed yield (1588 kg ha<sup>-1</sup>) over the control. In case of different levels of B an increase in growth i.e., number of branches plant<sup>-1</sup> and major yield components viz., pods plant<sup>-1</sup> and seeds pods<sup>-1</sup> were recorded along with higher seed and biological yield with the application of 1.0 kg B ha<sup>-1</sup> as compared to control. Suggested that application of 30 kg S ha<sup>-1</sup> and 1 kg B ha<sup>-1</sup> found suitable for obtaining higher productivity and quality of soybean with higher profitability under south-eastern plain zone of Rajasthan.

Fahmina *et al.* (2009) evaluated the effect of P and S and their interaction on the growth and yield of soybean (*Glycine max* L.) and results showed that Individual application of different levels of phosphorus and sulphur showed significant effect on yield and yield attributes. The plant height, number of primary branch plant<sup>-1</sup>, number of leaves plant<sup>-1</sup>, stover yield increased significantly up to 50 kg P ha<sup>-1</sup>. On the other hand, numbers of pods plant<sup>-1</sup>, number of seeds plant<sup>-1</sup>, thousand seed weight, grain yield, biological yield increased significantly up to 30 P<sub>2</sub>O<sub>5</sub> per kg ha<sup>-1</sup>.

<sup>1</sup>. However, in case of S, the positive response was observed only upto 20 kg S ha<sup>-1</sup>. The combined application of phosphorus @ 30 kg P ha<sup>-1</sup> and sulphur @ 20 kg S ha<sup>-1</sup> gave rise to the highest number of pods plant<sup>-1</sup>, number of seeds plant<sup>-1</sup>, thousand seed weight, and in turn produced highest grain yield. Thus, the combined application of 30 kg P ha<sup>-1</sup> and 20 kg Sulphur ha<sup>-1</sup> may be considered to be optimum for getting higher yield of soybean.

Farhad *et al.* (2009) studied the role of potassium and sulphur on the growth, yield and oil content of soybean and found that sulphur fertilizer had significant effect on yield and yield attributes of soybean. Application of sulphur @ 20 kg ha<sup>-1</sup> produced the highest plant height, seed yield. Combined application of Potassium @ 40 kg ha<sup>-1</sup> and sulphur @ 20 kg ha<sup>-1</sup> resulted the highest seed yield, plant height, 1000-seed weight, straw yield, protein and oil contents of soybean. On the other hand, in all the cases the lower response was found from the control treatment.

Kumar and Sidhu (2010) conducted greenhouse experiment with soybean grown on sulphur (S) and boron (B) deficient calcareous soil to observed the influence of increasing sulphur and boron levels on yield and its attributing characters at different growth stages. The highest dry matter yield at 55 days after sowing, DAS (19.3 g pot<sup>-1</sup>) and maturity (straw yield 25.2 g pot<sup>-1</sup> and grain yield 7.3 g pot<sup>-1</sup>) was recorded with B 0.44, S 13.4 treatment combination. The combined applications of sulphur and boron yielded highest oil content with B 0.44, S 13.4 (21.7%) treatment level. Chlorophyll 'a' and 'b' increased significantly with successive levels of sulphur and boron addition at 55 DAS.

Tahir *et al.* (2012) evaluates the production potential of soybean (*Glycine max* L.) in response to boron and found that the application of boron @ 2 kg ha<sup>-1</sup> significantly increased plant height, number of pods plant<sup>-1</sup>, number of pods bearing branches, thousand seed weight, grain yield, biological yield, harvest index and protein content while maximum oil contents were obtained when 8 kg ha<sup>-1</sup> boron was used which was statistically at par with treatment 2 kg ha<sup>-1</sup>. While maximum net income was also obtained by application of boron at 2 kg ha<sup>-1</sup> under agro ecological conditions of Pakistan.

Choudhary *et al.* (2012) investigated S and Zn application effects on soybean (*Glycine max* L.) yield, yield attributing traits and quality parameters. The

results revealed that all these mentioned parameters were significantly affected by the addition of sulphur and zinc doses. Highest grain yield 14.59 and 14.25 g pot<sup>-1</sup> were obtained when S (40 ppm) and Zn (5 ppm) were applied individually. The highest yield and the yield attributes viz; plant height, branches plant<sup>-1</sup>, capsule plant<sup>-1</sup>, grains capsule<sup>-1</sup>, 100-grain weight were also obtained for the treatment combination of 40 ppm S and 5 ppm Zn.

Jeena Mathew and Sumam George (2013) reported that the effect of sulphur (S) and boron (B) on the productivity of sesame (*Sesamum indicum* L.) in an *Entisol* of Kerala. And found that S and B acted synergistically in enhancing the biometric characters, root characters, yield and yield attributes of sesame, and nutrient uptake by grain and straw. The available nutrient status was also significantly improved by the application of these nutrients.

Ram *et al.* (2014) studied the response of soybean (*Glycine max* L. Merrill) to different levels of sulphur and boron. The highest grain yield, protein, oil content, gross and net returns of soybean were recorded with 40 kg S ha<sup>-1</sup>, which were statistically at par with 30 kg S ha<sup>-1</sup> but significantly higher than other levels of sulphur. The productivity in 40 kg S ha<sup>-1</sup> was enhanced 61.9% over the absolute control. The boron level of 1.5 kg ha<sup>-1</sup> recorded the highest grain yield, gross and net returns, being statistically at par with 1.0 kg B ha<sup>-1</sup> but significantly higher than 0.5 kg B ha<sup>-1</sup>.

## **2.2 To determine the effect of Sulphur and Boron application on uptake of Nitrogen, Phosphorus, Potassium, Sulphur and Boron by soybean**

Swarup *et al.* (2001) estimated S uptake by various crops was computed to be 133,186 tonnes. Four crops accounted for 82% of total S uptake were Soybean 32 (29.4%), wheat (28.9%), chickpea (15.4%) and mustard (8.3%).

Singh (2003) found that the stover yields of soybean were significantly influenced by graded levels of S and B application. The total S and B uptake by crop increased significantly with increased levels of up to 60 kg S + 2.0 kg B ha<sup>-1</sup>. The total S uptake at 0 and 60 kg S ha<sup>-1</sup> was 10.27 and 16.72 kg ha<sup>-1</sup>, respectively, whereas total B uptake at 0 and 2.0 kg B ha<sup>-1</sup> was 98.58 and 198.72 kg ha<sup>-1</sup>, respectively.

Brar *et al.* (2006) studied that S uptake by the mustard-green gram system in 33 Punjab was  $31.7 \text{ kg S ha}^{-1} \text{ -year}$  without S application. When mustard in the system received  $45 \text{ kg S ha}^{-1}$ , total S uptake was  $56.1 \text{ kg ha}^{-1}$  corresponding to a yield level of  $1572 \text{ kg mustard seed}$  and  $766 \text{ kg green gram ha}^{-1}$ . This legume-crucifer system absorbed  $24 \text{ kg S per tonne seed production}$ . Gupta and Jain (2006) reported that for one tonne seed production, S uptake was  $19.2 \text{ kg}$  by mustard and  $5.6 \text{ kg}$  by pearl millet.

Ismail *et al.* (2009) evaluated the interaction effect of sulphur and boron on yield, nutrient uptake and nutrient availability in soil after harvest of the crop. The results clearly indicated that application of sulphur as well as boron in their graded doses increased the grain and dry matter yield of soybean, uptake of N, P, S and B in soil significantly after harvest of crop. The enhancement in these parameters were recorded with combined effect of sulphur upto  $60 \text{ kg S ha}^{-1}$  and that of boron to the tune of  $20 \text{ kg borax ha}^{-1}$  application levels indicating their sufficient need for a crop like soybean.

Choudhary *et al.* (2012) investigated S and Zn application effects on soybean (*Glycine max* L.) yield, yield attributing traits and quality parameters. The experiment comprised four levels of sulphur and zinc. The results revealed that all these mentioned parameters were significantly affected by the addition of sulphur and zinc doses. Highest grain yield were obtained when S (40 ppm) and Zn (5 ppm) were applied individually. On the other hand content and uptake of Zn increased up to 40 ppm S and thereafter decreases at 60 ppm S level. Contents of S increased with increase in S doses up to 60 ppm. However the values at 40 and 60 ppm were statistically at par. Zinc content increased up to 20 ppm S and thereafter decreased.

Ram *et al.* (2014) studied the response of soybean (*Glycine max* L. Merrill) to different levels of sulphur and boron application. The highest S and B uptake were recorded in  $40 \text{ kg S ha}^{-1}$  and  $1.5 \text{ kg B ha}^{-1}$  respectively.

## CHAPTER – III

### METHODS AND MATERIALS

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A field experiment was conducted at Krishi Vigyan Kendra, Kawardha farm; Kabirdham (C.G.) to study the “Influence of Sulphur and Boron on yield of Soybean (*Glycine max*) in *Vertisols* of Kabirdham District” was carried out during *kharif* season 2014. Details of the materials used and the experimental techniques adopted during the course of study are described in this chapter.

#### **3.1 Location and experimental site**

The experiment was conducted at KVK, Kawardha farm, Kabirdham (C.G.). District Kabirdham extends in 4447.05 Sq km areas between 21°32' to 22°28' North latitude and 80°48' to 81°48' east longitude. The central east and southern part of the district is plain, whereas the northern and western part is mountainous. Mainly Black, Kanhar and Dorsa soil is found in the district, in which Nitrogen, Phosphorus, Potash and Sulphur is available in medium quantity, whereas Zinc and Sulphur elements lack.

#### **3.2 Climate and weather condition**

The district enjoys a subtropical climate characterized by hot summer and monsoon rainfall followed by dry and cold winter season. The normal average rainfall of the district is 1270 mm. The annual temperature varies from 42.2% (summer) to 11°C (winter). The relative humidity varies from 86% (rainy season) to 36% (winter).

#### **3.3 Soil characteristic**

In order to determine the mechanical and chemical composition of experimental plot, soil samples were collected randomly from the experimental site up to 20 cm depth with the help of soil auger. A composite sample was drawn from mixed representative samples by dividing repeatedly till the amount of representative samples remain about 250 gm and then it was used for analysis. The detailed physico-chemical properties of the soil are presented in Table 3.1

**Table 3.1: Physico-chemical properties of soil**

S.No.	Soil Properties	Values
1	Mechanical composition	
	Sand (%)	21.4
	Silt (%)	28.2
	Clay (%)	50.4
2	CEC (cmol(p+)/kg)	41.5
3	Electrical conductivity (dSm-1)	0.49
4	Organic Carbon (%)	0.47
5	Available N (kg/ha)	225.45
6	Available P (kg/ha)	9.6
7	Available K (kg/ha)	474
8	Available S (kg/ha)	22.15
9	Available B (mg/ha)	0.88

### 3.4 Cropping season

The field experiment was conducted during *kharif* season 2014.

### 3.5 Test crop

Soybean cultivar 'JS-335' was the test crop for experiment. This cultivar has a general height of 40-55 cm with erect branches. It flowers in about 45 DAS and takes 90 to 100 days to mature. The yield potential is 18-22 quintals ha<sup>-1</sup>. The seed size is moderate, yellow in colour and contains 42 to 44% protein and 20-21% oil, early maturity, good germination, resistance to major diseases and pest. It is tolerant to stem fly, suitable for early sowing under rainfed and irrigated conditions, suitable for double cropping suitable for shallow light to moderately & heavy deep black soil.

### 3.6 Experimental details:

<b>Crop</b>	:	Soybean
<b>Variety</b>	:	JS-335
<b>Design of experiment</b>	:	Randomized complete block design (with Factorial arrangement)
<b>Number of treatments</b>	:	16
<b>Number of replications</b>	:	03
<b>plot size</b>	:	5 m × 3 m = 15 m <sup>2</sup>
<b>Spacing</b>	:	30 cm x 10 cm
<b>Date of sowing</b>	:	04-07-2014

**Table 3.2: Treatment details:****T<sub>1</sub>- S<sub>1</sub>B<sub>1</sub>****T<sub>2</sub>- S<sub>1</sub>B<sub>2</sub>****T<sub>3</sub>- S<sub>1</sub>B<sub>3</sub>****T<sub>4</sub>- S<sub>1</sub>B<sub>4</sub>****T<sub>5</sub>- S<sub>2</sub>B<sub>1</sub>****T<sub>6</sub>- S<sub>2</sub>B<sub>2</sub>****T<sub>7</sub>- S<sub>2</sub>B<sub>3</sub>****T<sub>8</sub>- S<sub>2</sub>B<sub>4</sub>****T<sub>9</sub>- S<sub>3</sub>B<sub>1</sub>****T<sub>10</sub>- S<sub>3</sub>B<sub>2</sub>****T<sub>11</sub>- S<sub>3</sub>B<sub>3</sub>****T<sub>12</sub>- S<sub>3</sub>B<sub>4</sub>****T<sub>13</sub>- S<sub>4</sub>B<sub>1</sub>****T<sub>14</sub>- S<sub>4</sub>B<sub>2</sub>****T<sub>15</sub>- S<sub>4</sub>B<sub>3</sub>****T<sub>16</sub>- S<sub>4</sub>B<sub>4</sub>**

Where;

 $S_1 = 0$  kg S/ha,  $S_2 = 15$  kg S/ha,  $S_3 = 30$  kg S/ha,  $S_4 = 45$  kg S/ha $B_1 = 0$  kg B/ha,  $B_2 = 0.5$  kg B/ha,  $B_3 = 1.0$  kg B/ha,  $B_4 = 1.5$  kg B/ha

<b>Fertilizer sources</b>	<b>Content</b>	<b>Method of application</b>
Urea	46% N	Basal
DAP	18% N, & 46% P <sub>2</sub> O <sub>5</sub>	Basal
MOP	60% K <sub>2</sub> O	Basal
Benonite sulphur	90% Sulphur	Basal
Boric acid	17% Boron	Basal

### **3.7 Field preparation**

The preparatory tillage operation was given to the experimental field by ploughing with tractor drawn cultivator followed by harrowing and breaking clods with rotavater. The set of sixteen treatments were imposed on same layout and replicated third, thus making a total of 48 plots. Allotment of the each treatment was done by restricted randomization.

### **3.8 Fertilizer application**

Recommended dose of nitrogen, phosphorus and potassium @ 25:60:30 kg ha<sup>-1</sup> through Urea (46% N), DAP (18% N and 46% P<sub>2</sub>O<sub>5</sub>) and muriate of potash (60% K<sub>2</sub>O), respectively were uniformly applied as basal to each plot. Sulphur was applied through bentonite sulphur powder (field grade) @ 0, 15, 30 and 45 kg ha<sup>-1</sup> as basal. Boron was applied through boric acid (17.0% B) @ 0, 0.5, 1.0, and 1.5 kg ha<sup>-1</sup> as basal.

### **3.9 Sowing**

The crop was sown on July 4<sup>nd</sup>, 2014 by hand dibbling the seeds into line @ 75 kg ha<sup>-1</sup>. The row x plant distance was kept 30 x 10 cm.

### **3.10 Harvesting**

Harvesting was done manually from net plot area when the seed became hard and leaves turned yellow in colour. The plants were left in plot for five days to dry in the sun. The crop was harvested on 12<sup>th</sup>, Oct. 2014 at maturity stage. Pod and seed yield were recorded separately in each treatment plot wise.

### **3.11 Threshing and winnowing**

Threshing of produce of each net plot was done manually by beating with wooden stick and after manual winnowing seed yield plot<sup>-1</sup> was noted. Stover yield was worked out after subtracting the seed yield from bundle weight.

### **3.12 Observation**

The experimental observations on crop and weeds are presented under the following heads.

### **3.12.1 Studies on crop**

For study of Influence of Sulphur and Boron on yield of Soybean, several observations were recorded on the growth parameters and yield attributing characters of crop. For recording pre-harvest and post-harvest observations, five plants were randomly selected from each plot and tagged.

#### **3.12.1.1 Pre-harvest studies**

##### **3.12.1.1.1 Plant height (cm)**

Height of five tagged plants in each plot was recorded in cm at harvest and then average was worked out and used for statistical analysis. Height was measured in centimetre from ground surface to the tip of main stem.

#### **3.12.1.2 Post-harvest studies**

##### **3.12.1.2.1 Number of pods plant<sup>-1</sup>**

To study the influence of different treatment on pod formation in soybean crop, total number of pods was recorded from five randomly tagged plants and mean was worked out by dividing the total number of pods by five and used for statistical analysis.

##### **3.12.1.2.2 100-seed weight (g)**

Randomly seed samples were taken from each net plot. 100 healthy seeds from the produce of each plot were counted and same were oven dried till constant weight and then weight was recorded in gram accurately by using an electronic digital balance.

##### **3.12.1.2.3 Seed yield (q ha<sup>-1</sup>)**

Seed yield of the net plot was noted down, after threshing, winnowing and drying then calculated in quintal ha<sup>-1</sup> with appropriate multiplication factor.

##### **3.12.1.2.4 Stover yield (q ha<sup>-1</sup>)**

The harvested produce from each net plot was tied in bundles separately. Stover yield of plot was calculated after subtraction of seed yield from bundle weight. Bundle weight was recorded with the help of spring balance and converted into quintal ha<sup>-1</sup>.

### 3.12.1.2.5 Harvest Index (HI %)

The harvest index was determined by using the formula given by Donald (1962).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Where,

$$\text{Economic yield} = \text{Seed yield}$$

$$\text{Biological yield} = \text{Seed yield} + \text{Stover yield}$$

## 3.13 Soil and Plant analysis

### 3.13.1 Soil analysis

#### 3.13.1.1 pH

Soil pH was determined by glass electrode pH meter, taking 1:2.5 soil water suspension after stirring it for 30 minutes and measured by a pH meter as described by Jackson (1967).

#### 3.13.1.2 Electrical Conductivity (EC)

The sample used for pH determination was allowed to stand overnight and conductivity of the supernatant liquid was determined by Conductivity meter as described by Jackson (1967).

#### 3.13.1.3 Cation Exchange Capacity (CEC)

The cation exchange capacity was determined by leaching the soil with neutral normal ammonium acetate as described by Black (1965).

#### 3.13.1.4 Organic carbon

Organic carbon was determined by Walkley and Black's rapid titration method (1934) as described by Piper (1967).

#### 3.13.1.5 Available Nitrogen

Available N was determined by alkaline permanganate method of Subbiah and Asija (1956).

### 3.13.1.6 Available Phosphorus

The available phosphorus content of the soil was determined by Olsen's method (Olsen *et al.*, 1954).

### 3.13.1.7 Available Potassium

Available K was determined by Flame-photometer method (Chapman and Pratt, 1961).

### 3.13.1.8 Available Sulphur

Available Sulphur in soil was determined by the  $\text{CaCl}_2 \cdot \text{H}_2\text{O}$  (0.15% Solution) by turbidometric method (Williams and Steinbergs, 1959).

Reagents:

1. 0.15 % calcium chloride solution: Dissolve 1.5 g of calcium chloride dehydrated ( $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ ) in about 500 ml of distilled water and make the volume to 1L.
2. Barium chloride crystals: Grind  $\text{BaCl}_2$  (AR grade) crystals pass through a 30 mesh sieve and retain on a 60 mesh sieve, and store in a clean bottle.
3. Gum acacia solution: Dissolve 0.25 g of Gum acacia in distilled water and dilute to 100 ml.

#### Procedure:

10 g of air-dry soil was taken in a 150 ml conical flask and add 50 ml of 0.15%  $\text{CaCl}_2$  solution. Shaken for 30 minutes on a rotary shaker and filter through Whatman No. 42 filter paper. Take 10 ml of the clean filtrate was taken in a 25 ml volumetric flask, added 1 ml of 0.25 % gum acacia solution, made up the volume with distilled water and shaken well manually, added 1 gm of  $\text{BaCl}_2$  crystal each flask and swirled to dissolve the crystals within 5-30 minutes of development turbidity (white colour), read the absorbance 440 nm through spectrophotometer.

### 3.13.1.9 Available Boron

Available boron in soil was determined by the Azomethine -H (John *et al.* 1975).

**Reagents:**

1. Buffer solution: Dissolve 250 g of ammonium acetate and was dissolved 15 g of EDTA (disodium salt) in 400 ml of distilled water, slowly add 125 ml of glacial acetic acid and mix thoroughly.
2. Azomethine –H reagent: Dissolve 0.45 g of azomethine- H in 100 ml of 1% L – Ascorbic acid solution. Store in polypropylene bottle in a refrigerator. Prepare fresh solution every week.
3. Activated charcoal.

**Procedure :**

20 g of air -dry (20 –30 mesh) soil sample was taken in 250 ml quartz or other boron –free conical flask and added 40 ml of distilled water. Further 0.5 g activated charcoal and boiled for 5 minutes on a hot plate, filtered immediately through whatman No. 42 filter paper. Cool the contents to room temperature and transferred 1 ml aliquot in 10 or 15 ml polypropylene tubes. Added 2 ml of buffer solution and mix. Added 2 ml of azomethene –H reagent, mixed and after 30 minutes read the absorbance at 420 nm on a spectrophotometer.

**3.13.2 Plant analysis**

Plant and seed sample dried at 550<sup>0</sup> C in an oven for 24 hours and were grinded and used for analysis.

**3.13.2.1 Nitrogen content**

Nitrogen content in digested grain and plant samples were determined by using Micro-kjeldahl method as described by Chapman and Pratt (1961).

**3.13.2.2 Phosphorus content**

Phosphorus content of digested grain and plant samples was estimated by development of Vanadomolybdo-phosphoric acid yellow colour method using double beam spectrophotometer at wavelength (Jackson, 1967).

**3.13.2.3 Potassium content**

Potassium content was determined by flame photometer method, as described by Chapman and Pratt (1961).

**3.13.2.4 Sulphur content**

Sulphur by turbidimetric method (Chesnin and Yien, 1950),

### 3.13.2.5 Boron content

Boron was determined by the azomethine-H method of John *et al*, (1975)

### 3.13.2.6 Nutrient uptake

Macro (N, P, and K), secondary nutrient (S) & micro nutrient (B) uptake in seed & stover yields were computed by multiplying their respective nutrient contents with yields using of following formula:

Nutrient uptake (kg/ha) in seed = Concentration (%) x straw yield ( $q\ ha^{-1}$ )

Nutrient uptake (kg/ha) in stover = Concentration (%) x straw yield ( $q\ ha^{-1}$ )

### 3.14 Statistical analysis

The experiment was laid out in randomized complete block design with factorial arrangement. The data obtained on various characters under study were analysed statistically by using the method of analysis of variance for randomized complete block design and significance was tested by Gomez and Gomez, 1984.

## CHAPTER-IV RESULTS AND DISCUSSION

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A field experiment was conducted during *Kharif season* of 2014 at farm of Krishi Vigyan Kendra Kawardha, district Kabhirdham (C.G.) to study the “Influence of Sulphur and Boron on yield of Soybean (*Glycine max*) in *Vertisols* of Kabirdham District”

The data recorded on various growth parameters, yield attributing characters, soil and plant analyses, nutrient uptake, available nutrient status on post harvest soil etc. are briefly discussed in this chapter under following heads and sub heads.

### 4.1 Growth and Yield Parameters

#### 4.1.1 Plant Height (cm)

The data on plant height of soybean is presented in Table 4.1 which ranged from 35.43 cm to 43.90 cm. Irrespective of the boron level, application of sulphur significantly affected plant height and maximum height (42.89 cm) was observed with application of 45 kg S ha<sup>-1</sup> followed by 30 kg S ha<sup>-1</sup> (41.63 cm) and 15 kg S ha<sup>-1</sup> (39.18 cm). However, plant height with application of 15 kg S ha<sup>-1</sup> (39.18 cm) did not differ significantly with control (37.05 cm) where no sulphur was applied (0 kg S ha<sup>-1</sup>) and both were statistically at par.

Plant height with application of 0, 0.5, 1.0 and 1.5 kg B ha<sup>-1</sup> were 38.03, 40.99, 40.75 and 40.98 cm respectively and were statistically at par.

Maximum plant height (43.90 cm) was observed in the treatment T<sub>16</sub> (S<sub>45</sub>B<sub>1.5</sub>) and minimum (35.43 cm) in control where no sulphur and boron were applied i.e. T<sub>1</sub> (S<sub>0</sub>B<sub>0</sub>). Interaction effect between sulphur and boron level was found to be non-significant.

#### 4.1.2 Number of Pods Plant<sup>-1</sup>

The data presented in Table 4.1 clearly indicated that number of pods plant<sup>-1</sup> significantly varied due to application of different sulphur levels. Number of pods plant<sup>-1</sup> ranged from 42.00 to 50.04. Minimum number was associated 0 kg S ha<sup>-1</sup>

which was increased with increasing level of sulphur and maximum number was observed with 45 kg S ha<sup>-1</sup>.

Maximum number of pods plant<sup>-1</sup> (47.17) was recorded due to application of 1.5 kg B ha<sup>-1</sup> followed by 1.0 kg B ha<sup>-1</sup> (46.92), 0.5 kg B ha<sup>-1</sup> (46.75) and minimum number with 0 kg B ha<sup>-1</sup> (44.33). However, number of pods plant<sup>-1</sup> under different boron levels did not differ significantly.

Interaction of sulphur and boron level did not have any significant effect on the number of pods plant<sup>-1</sup> and maximum (50.04) and minimum (42.00) value were associated with T<sub>16</sub>(S<sub>45</sub>B<sub>1.5</sub>) and T<sub>1</sub>(S<sub>0</sub>B<sub>0</sub>) respectively.

#### 4.1.3 100 Seed Weight (g)

Different level of sulphur had significant effect on 100 seed weight (Table 4.1). The highest weight of 100 seed (12.32 g) was found with 30 kg S ha<sup>-1</sup> and the lowest 100 seed weight (10.55 g) was found with 0 kg S ha<sup>-1</sup>. 100 seed weight with application of 30 kg S ha<sup>-1</sup> and 45 kg S ha<sup>-1</sup> (11.79 g) were found to be statistically at par with each other but significantly higher than that of 15 kg S ha<sup>-1</sup> (11.47 g) and 0 kg S ha<sup>-1</sup> (10.55 g)

Irrespective of the sulphur level, boron level had significant effect on 100 seed weight. 100 seed weight of soybean was increased with increase in boron level up to 1.0 kg B ha<sup>-1</sup> and beyond this level 100 seed weight was decreased. 100 seed weight with 0 kg B ha<sup>-1</sup>, 0.5 kg B ha<sup>-1</sup>, 1.0 kg B ha<sup>-1</sup> and 1.5 kg B ha<sup>-1</sup> were 10.41, 11.53, 12.25 and 11.94 respectively.

Interaction of sulphur and boron level did not have any significant effect on 100 seed weight. Highest 100 seed weight (12.92 g) was observed with T<sub>11</sub>(S<sub>30</sub>B<sub>1.0</sub>) and lowest 100 seed weight (10.31 g) was recorded in T<sub>1</sub>(S<sub>0</sub>B<sub>0</sub>).

#### 4.1.4 Seed Yield (q ha<sup>-1</sup>)

The data pertaining to seed yield of soybean ranged from 13.72 to 21.83 q ha<sup>-1</sup> (Table 4.1). Significant difference was observed in respect of seed yield with different sulphur level at 5 % level of probability. The highest seed yield (21.04 q ha<sup>-1</sup>) was obtained with 30 kg S ha<sup>-1</sup>. The second highest yield (19.67 q ha<sup>-1</sup>) was

obtained from 45 kg S ha<sup>-1</sup>. The lowest one 14.15 q ha<sup>-1</sup> was associated with 0 kg S ha<sup>-1</sup>.

Seed yield of soybean was significantly influenced by boron level. Table 4.1 showed that seed yield was significantly higher (18.82 q ha<sup>-1</sup>) with 1.0 kg B ha<sup>-1</sup> followed by 1.5 kg B ha<sup>-1</sup> (18.71 q ha<sup>-1</sup>) and 0.5 kg B ha<sup>-1</sup> (18.23 q ha<sup>-1</sup>) whereas the lowest seed yield (16.02 q ha<sup>-1</sup>) was obtained from 0 kg B ha<sup>-1</sup>.

The highest seed yield (21.83 q ha<sup>-1</sup>) was recorded with T<sub>11</sub> (S<sub>30</sub>B<sub>1.0</sub>) and the lowest one (13.72 q ha<sup>-1</sup>) with T<sub>1</sub> (0 kg B ha<sup>-1</sup> and 0 kg S ha<sup>-1</sup>). But interaction effect between sulphur and boron level was found to be non-significant.

#### 4.1.5 Stover Yield (q ha<sup>-1</sup>)

It is obvious from the table 4.1 that sulphur level had significant influence on the stover yield of soybean. The highest stover yield of 22.55 q ha<sup>-1</sup> was recorded with 30 kg S ha<sup>-1</sup> and the lowest one (16.29 q ha<sup>-1</sup>) was found with 0 kg S ha<sup>-1</sup>.

Boron level showed significant influence on stover yield of soybean. The stover yield was more (21.05 q ha<sup>-1</sup>) with 1.0 kg B ha<sup>-1</sup> as compared to the stover yield of 20.88 and 20.06 q ha<sup>-1</sup> which was associated with 1.5 and 0.5 kg B ha<sup>-1</sup> respectively and lowest stover yield (17.94 q ha<sup>-1</sup>) was obtained from 0 kg B ha<sup>-1</sup>.

The stover yield of soybean did not vary significantly by the interaction effect of sulphur and boron level.

#### 4.1.6 Harvest Index (%)

To study the partitioning behaviour of seed and rest of the vegetative biomass of the plant influenced by different combinations of sulphur and boron under study, harvest index values for treatments were calculated and presented in Table 4.1.

Highest harvest index (48.25 %) was recorded with 30 kg S ha<sup>-1</sup> followed by 15 kg S ha<sup>-1</sup> (47.24 %) and 45 kg S ha<sup>-1</sup> (46.97 %) and lowest harvest index (46.42 %) with 0 kg S ha<sup>-1</sup> but the differences were non-significant.

Among boron level the highest value of harvest index (47.49 %) was recorded with 0.5 kg B ha<sup>-1</sup>.

Interaction of sulphur and boron level did not affected harvest index of soybean and highest harvest index 48.94 % was observed with T<sub>10</sub> (S<sub>30</sub>B<sub>0.5</sub>) and it was statistically identical at par with harvest index of T<sub>1</sub> (0 kg S ha<sup>-1</sup> and 0 kg B ha<sup>-1</sup>).

Among the fertilizer elements sulphur requirement of oilseed crops is quite high as compared to other crops (Das and Das, 1994). The above results are in conformity with the results of Joshi and Billore (1998) who reported a gradual increase in the yield attributes of soybean with increasing levels of sulphur. Chaubey *et al.* (2000) observed that numbers of primary branches, pods per plant, plant height and 100 kernel weight of groundnut were significantly higher by the application of sulphur. Allam (2002) reported that application of sulphur fertilizer increased yield between 20% and 42% in field experiments. Increased grain yield due to increased levels of sulphur might be due to improvement in yield components like number of pods plant<sup>-1</sup>, higher seed index etc. These findings were also supported by Mahale *et al.* (1985), Das (1993), Halepyati (2001), Singaravel *et al.* (2006).

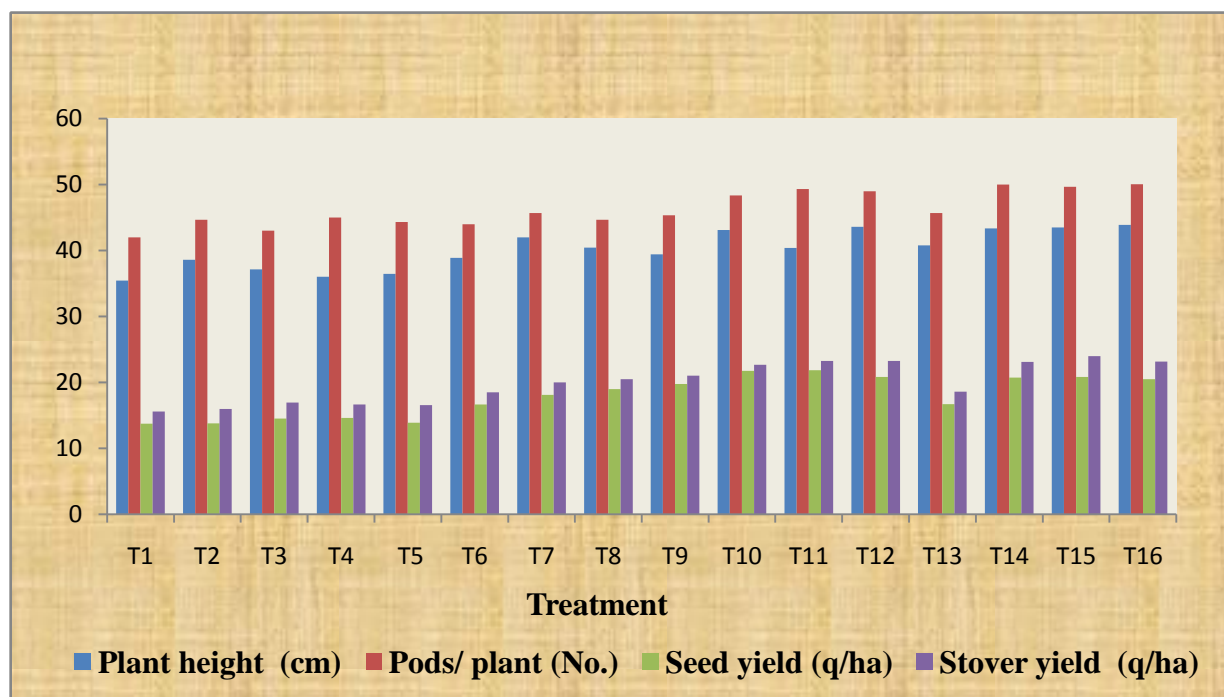
With increased supply of sulphur, the process of tissue differentiation from somatic to reproductive, meristematic activity and development might have increased, resulting in increase in number and size of leaves (Mengel and Kirkby, 1987). As in soybean, sink lies in leaves, when supply of sulphur is optimum, greater translocation of photosynthates occur from leaves to the site, i.e. seed (Mengel and Kirkby, 1987). The sum total effect will be higher seed yield. The results confirm the findings of Kumar *et al.* (1992) and Sarkar *et al.* (2002).

Tripathy *et al.* (1999) also conclusively suggested that application of boron increased pods per plant in groundnut.

Results are in accordance with that of Singh *et al.* (2003), who documented that crop yields, in general, have been promoted by regular application of boron. Chowdhury *et al.* (2000) also reported that seed yield of cowpea increased significantly with the increase in boron application.

**Table 4.1 : Effect of sulphur and boron on growth, yield attributes and yield of soybean**

Treatment	Plant height (cm)	Pods plant <sup>-1</sup> (No.)	100 seed weight (g)	Seed yield (q ha <sup>-1</sup> )	Stover yield (q ha <sup>-1</sup> )	Harvest Index (%)
T <sub>1</sub> - S <sub>0</sub> B <sub>0</sub>	35.43	42.00	10.31	13.72	15.57	46.51
T <sub>2</sub> - S <sub>0</sub> B <sub>0.5</sub>	38.57	44.67	10.34	13.77	15.98	46.30
T <sub>3</sub> - S <sub>0</sub> B <sub>1.0</sub>	37.13	43.00	10.73	14.52	16.96	46.16
T <sub>4</sub> - S <sub>0</sub> B <sub>1.5</sub>	36.03	45.00	10.80	14.60	16.64	46.73
T <sub>5</sub> - S <sub>15</sub> B <sub>0</sub>	36.47	44.33	10.45	13.90	16.56	46.03
T <sub>6</sub> - S <sub>15</sub> B <sub>0.5</sub>	38.90	44.00	10.57	16.66	18.49	47.39
T <sub>7</sub> - S <sub>15</sub> B <sub>1.0</sub>	41.97	45.67	12.46	18.12	20.02	47.47
T <sub>8</sub> - S <sub>15</sub> B <sub>1.5</sub>	40.43	44.67	12.39	18.96	20.48	48.08
T <sub>9</sub> - S <sub>30</sub> B <sub>0</sub>	39.43	45.33	10.34	19.78	21.04	48.47
T <sub>10</sub> - S <sub>30</sub> B <sub>0.5</sub>	43.13	48.33	13.66	21.75	22.66	48.94
T <sub>11</sub> - S <sub>30</sub> B <sub>1.0</sub>	40.40	49.33	12.92	21.83	23.26	48.32
T <sub>12</sub> - S <sub>30</sub> B <sub>1.5</sub>	43.57	49.00	12.36	20.81	23.25	47.25
T <sub>13</sub> - S <sub>45</sub> B <sub>0</sub>	40.80	45.67	10.54	16.68	18.59	47.27
T <sub>14</sub> - S <sub>45</sub> B <sub>0.5</sub>	43.37	50.00	11.56	20.73	23.10	47.33
T <sub>15</sub> - S <sub>45</sub> B <sub>1.0</sub>	43.50	49.67	12.87	20.82	23.96	46.38
T <sub>16</sub> - S <sub>45</sub> B <sub>1.5</sub>	43.90	50.04	12.20	20.47	23.15	46.89
<b>S levels (kg ha<sup>-1</sup>)</b>						
0	37.05	43.67	10.55	14.15	16.29	46.42
15	39.18	44.67	11.47	16.91	18.89	47.24
30	41.63	48.00	12.32	21.04	22.55	48.25
45	42.89	48.83	11.79	19.67	22.20	46.97
<b>B levels (kg ha<sup>-1</sup>)</b>						
0	38.03	44.33	10.41	16.02	17.94	47.07
0.5	40.99	46.75	11.53	18.23	20.06	47.49
1.0	40.75	46.92	12.25	18.82	21.05	47.08
1.5	40.98	47.17	11.94	18.71	20.88	47.24
<b>SEm±</b>						
S levels	0.90	0.93	0.43	0.74	0.78	0.58
B levels						
(S x B)	0.90	0.93	0.43	0.74	0.78	0.58
Interaction	1.80	1.86	0.86	1.47	1.55	1.17
<b>CD (P=0.05)</b>						
S levels	2.59	2.69	1.24	2.13	2.24	NS
B levels						
(S x B)	NS	NS	1.24	2.13	2.24	NS
Interaction	NS	NS	NS	NS	NS	NS



**Fig.4.1 :Effect of sulphur and boron on growth, yield attributes and yield of soybean**

## 4.2 Effect of sulphur and boron on nutrient content of soybean

### 4.2.1 Nitrogen Content (%)

Data on nitrogen content has been presented in Table 4.2. Maximum nitrogen content (5.81% in grain and 1.10 % in stover) was observed with application of 30 kg S ha<sup>-1</sup> whereas the minimum nitrogen content (5.67% in grain and 1.03 % in stover) with 0 kg S ha<sup>-1</sup>.

Table 4.2 showed that nitrogen content in seed and stover was comparatively higher (5.75 % and 1.10% respectively) with 1.5 and 1 kg B ha<sup>-1</sup> respectively over other boron levels.

The highest nitrogen content in seed (5.89 %) and stover (1.08 %) was found with T<sub>9</sub> (S<sub>30</sub>B<sub>0</sub>) and T<sub>10</sub> (S<sub>30</sub>B<sub>0.5</sub>) respectively and minimum (5.59 in seed and 0.99 in stover) in T<sub>1</sub> (S<sub>0</sub>B<sub>0</sub>).

Sulphur level, boron level and interaction between sulphur and boron level was found to have no significant effect on nitrogen content.

### 4.2.2 Phosphorus Content (%)

It is evident from the Table 4.2 that phosphorus content in seed of soybean ranged from 0.31 to 0.34 % and in stover from 0.115 to 0.147 %. Sulphur and boron levels and their interactions did not have any significant effect on phosphorus content in seed and stover of soybean.

### 4.2.3 Potassium Content (%)

Table 4.2 clearly indicated that the potassium content in stover was comparatively higher than potassium content in seed. Maximum potassium content (0.57% in seed and 1.22 % in stover) was observed with application of 30 kg S ha<sup>-1</sup>.

Application of 1 kg B ha<sup>-1</sup> resulted in maximum potassium content in seed (0.58%) and stover (1.22 %).

Sulphur level, boron level and interaction between sulphur and boron level did not produce significant variation in potassium content of soybean seed and stover.

**Table 4.2 Effect of sulphur and boron application on nutrient content in seed and stover of soybean**

Treatment	N content (%)		P content (%)		K content (%)		S content (%)		B content (mg kg <sup>-1</sup> )	
	Seed	stover	Seed	stover	Seed	stover	Seed	stover	Seed	stover
T <sub>1</sub> - S <sub>0</sub> B <sub>0</sub>	5.59	0.99	0.32	0.115	0.52	1.16	0.28	0.08	31.66	10.42
T <sub>2</sub> - S <sub>0</sub> B <sub>0.5</sub>	5.74	1.05	0.32	0.126	0.55	1.21	0.28	0.09	35.54	9.54
T <sub>3</sub> - S <sub>0</sub> B <sub>1.0</sub>	5.67	1.05	0.33	0.133	0.55	1.17	0.30	0.09	34.69	10.95
T <sub>4</sub> - S <sub>0</sub> B <sub>1.5</sub>	5.68	1.02	0.32	0.127	0.54	1.20	0.32	0.09	32.78	10.91
T <sub>5</sub> - S <sub>15</sub> B <sub>0</sub>	5.56	1.01	0.31	0.123	0.48	1.18	0.29	0.08	34.49	10.34
T <sub>6</sub> - S <sub>15</sub> B <sub>0.5</sub>	5.67	1.02	0.32	0.126	0.51	1.18	0.31	0.09	34.32	12.00
T <sub>7</sub> - S <sub>15</sub> B <sub>1.0</sub>	5.80	1.11	0.33	0.135	0.62	1.25	0.31	0.09	34.05	11.13
T <sub>8</sub> - S <sub>15</sub> B <sub>1.5</sub>	5.73	1.07	0.33	0.123	0.55	1.17	0.29	0.09	36.05	9.79
T <sub>9</sub> - S <sub>30</sub> B <sub>0</sub>	5.89	1.07	0.34	0.134	0.58	1.18	0.29	0.08	34.35	10.58
T <sub>10</sub> - S <sub>30</sub> B <sub>0.5</sub>	5.78	1.08	0.34	0.127	0.53	1.25	0.29	0.09	33.27	9.87
T <sub>11</sub> - S <sub>30</sub> B <sub>1.0</sub>	5.72	1.15	0.34	0.127	0.60	1.25	0.32	0.09	35.78	10.97
T <sub>12</sub> - S <sub>30</sub> B <sub>1.5</sub>	5.83	1.11	0.34	0.147	0.57	1.21	0.32	0.09	37.06	12.31
T <sub>13</sub> - S <sub>45</sub> B <sub>0</sub>	5.76	1.01	0.31	0.135	0.54	1.22	0.31	0.08	32.54	9.31
T <sub>14</sub> - S <sub>45</sub> B <sub>0.5</sub>	5.68	1.05	0.33	0.129	0.53	1.18	0.29	0.09	36.24	11.29
T <sub>15</sub> - S <sub>45</sub> B <sub>1.0</sub>	5.77	1.07	0.34	0.131	0.54	1.22	0.31	0.09	36.10	10.89
T <sub>16</sub> - S <sub>45</sub> B <sub>1.5</sub>	5.74	1.10	0.34	0.130	0.53	1.22	0.30	0.09	35.89	11.84
<b>S Levels</b> (kg ha <sup>-1</sup> )										
0	5.67	1.03	0.32	0.125	0.54	1.19	0.29	0.08	33.67	10.45
15	5.69	1.05	0.32	0.125	0.54	1.19	0.30	0.09	34.73	10.81
30	5.81	1.10	0.34	0.125	0.57	1.22	0.30	0.09	35.12	10.93
45	5.74	1.06	0.33	0.125	0.54	1.21	0.30	0.09	35.19	10.83
<b>B Levels</b> (kg ha <sup>-1</sup> )										
0	5.70	1.02	0.32	0.125	0.53	1.19	0.29	0.08	33.26	10.16
0.5	5.72	1.05	0.33	0.127	0.53	1.20	0.29	0.08	34.84	10.67
1.0	5.74	1.10	0.33	0.134	0.58	1.22	0.31	0.09	35.15	10.99
1.5	5.75	1.08	0.33	0.131	0.55	1.20	0.31	0.09	35.45	11.21
<b>SEm±</b>										
S Level	0.04	0.02	0.005	0.003	0.012	0.020	0.007	0.003	0.776	0.515
B Level	0.04	0.02	0.005	0.003	0.012	0.020	0.007	0.003	0.776	0.515
(SXB)	0.09	0.05	0.010	0.007	0.025	0.041	0.015	0.006	1.551	1.030
Interaction										
<b>CD(P=0.05)</b>										
S Level	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
B Level	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
(SXB)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction										

#### 4.2.4 Sulphur Content (%)

It is observed from the Table 4.2 that sulphur content in seed of soybean ranged from 0.28 to 0.32 % and in stover from 0.8 to 0.9 %. Sulphur and boron levels and their interactions did not have any significant effect on sulphur content in seed and stover of soybean.

#### 4.2.5 Boron Content ( $\text{mg kg}^{-1}$ )

Data on boron content has been presented in Table 4.2. It is clear that the content of boron in seed is more than that of boron content in stover. Boron content in seed with different levels of sulphur ranged from 33.67 to 35.19  $\text{mg kg}^{-1}$  and that of stover ranged from 10.45 to 10.93  $\text{mg kg}^{-1}$ .

Boron content in seed and stover was maximum (35.45 and 11.21  $\text{mg kg}^{-1}$ ) with application of 1.5  $\text{kg B ha}^{-1}$ . However, Sulphur level, boron level and interaction between sulphur and boron level was found to have no significant effect on boron content of soybean.

### 4.3 Effect of sulphur and boron on nutrient uptake by soybean

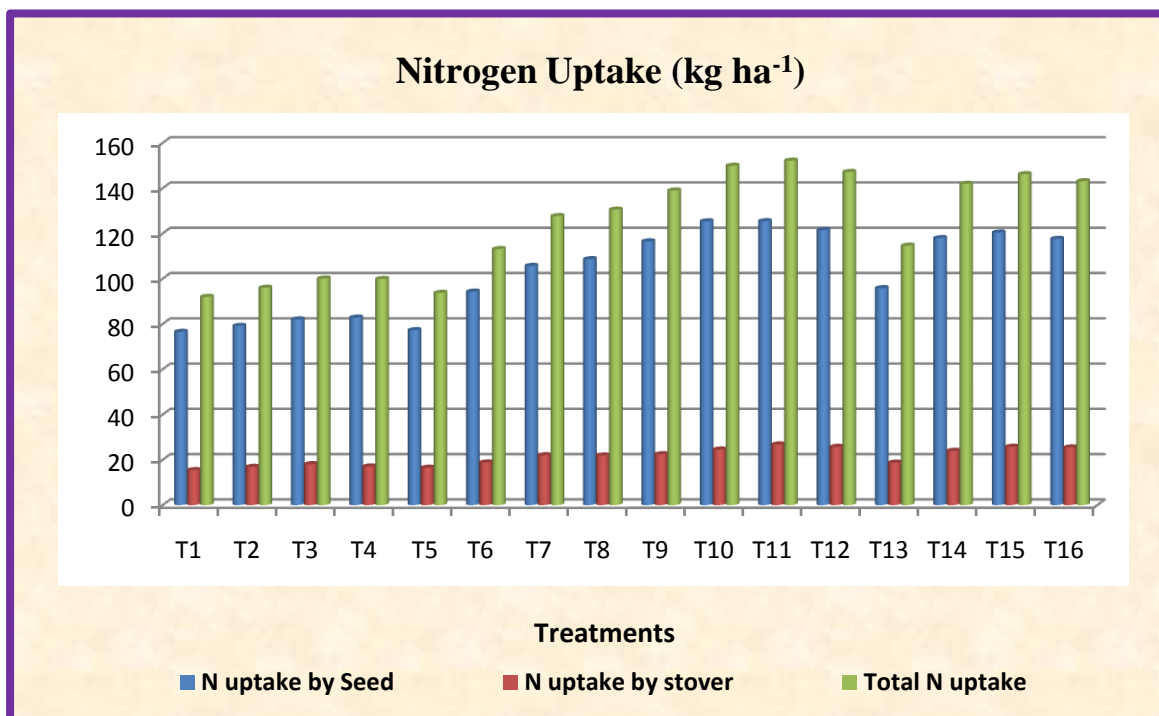
#### 4.3.1 Nitrogen Uptake ( $\text{kg ha}^{-1}$ )

Uptake of nitrogen by seed and stover of soybean together with total uptake is presented in Table 4.3 & Fig. 4.2 It is obvious that application of different sulphur level significantly influenced the nitrogen uptake by seed, stover and total uptake and maximum uptake (122.17, 24.86 and 147.03  $\text{kg ha}^{-1}$  in seed, stover and total respectively) was associated with 30  $\text{kg S ha}^{-1}$  and minimum uptake (80.12, 16.86 and 96.97  $\text{kg ha}^{-1}$  in seed, stover and total respectively) with the treatment where sulphur was not applied i.e. 0  $\text{kg S ha}^{-1}$ .

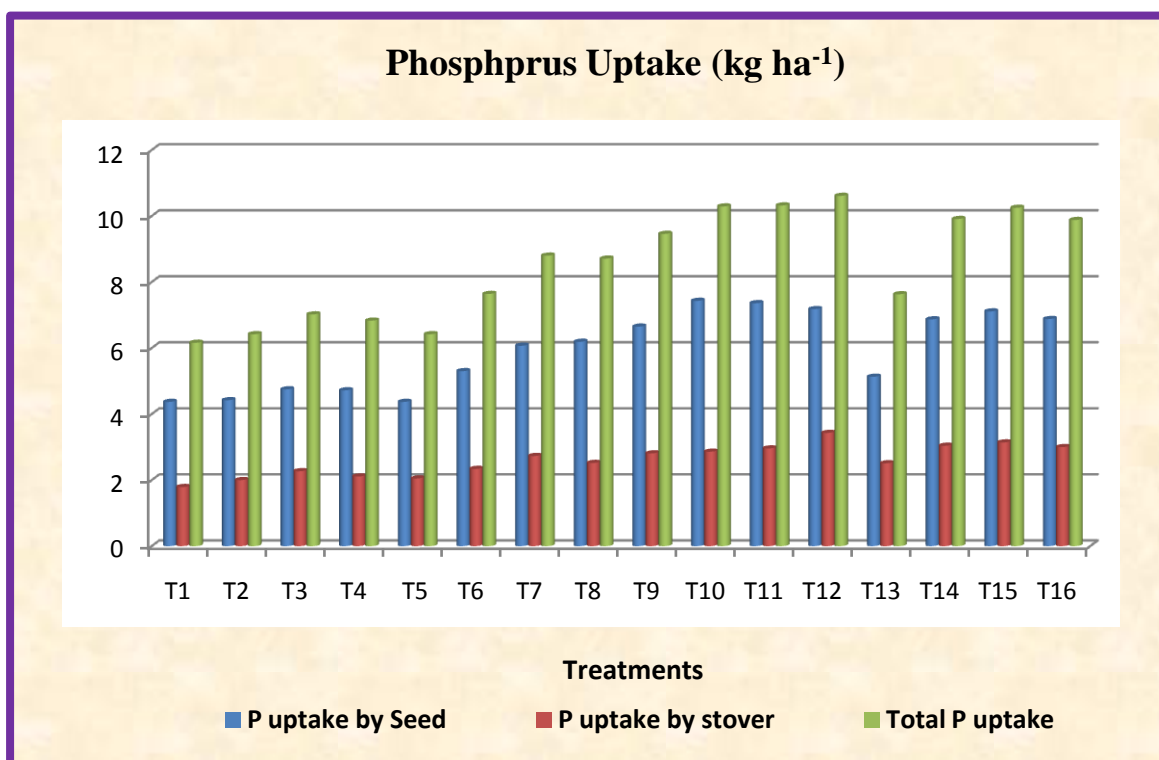
Increase in level of boron resulted in significantly increase in nitrogen uptake by seed and maximum uptake (108.36, 23.15 and 131.51  $\text{kg ha}^{-1}$  in seed, stover and total respectively) was observed in plot where boron was not applied (0  $\text{kg B ha}^{-1}$ ). Nitrogen uptake with 1.5  $\text{kg B ha}^{-1}$  and 1.0  $\text{kg B ha}^{-1}$  were statistically at par with each other but significantly higher over control i.e. 0  $\text{kg B ha}^{-1}$ .

Nitrogen uptake by soybean was not significantly affected by interaction of sulphur and boron level. However, maximum uptake (125.39, 26.76 and 152.15  $\text{kg ha}^{-1}$  in seed, stover and total respectively) was associated with 30  $\text{kg S ha}^{-1}$  and 1.5  $\text{kg B ha}^{-1}$ .

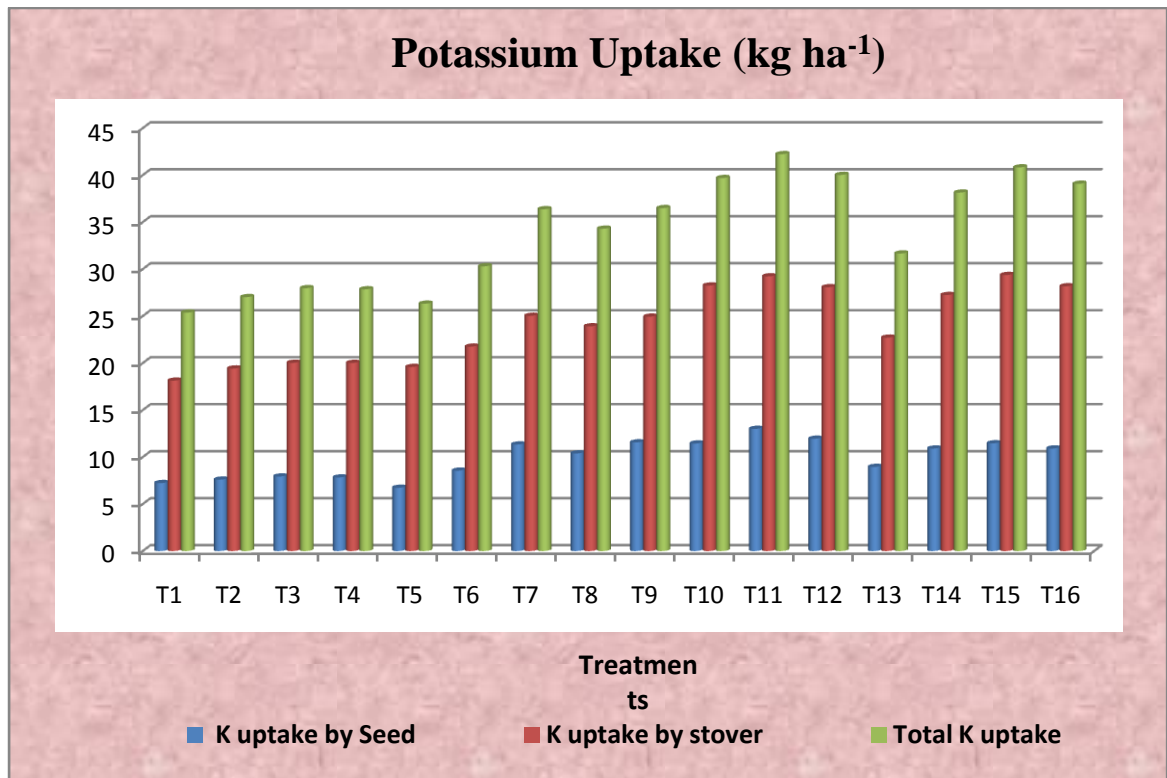




**Fig. 4.2 :Effect of sulphur and boron on nitrogen uptake ( $\text{kg ha}^{-1}$ )**



**Fig. 4.3 :Effect of sulphur and boron on Phosphorus uptake ( $\text{kg ha}^{-1}$ )**



**Fig. 4.4** :Effect of sulphur and boron on Potassium uptake (kg ha<sup>-1</sup>)

### 4.3.2 Phosphorus Uptake ( $\text{kg ha}^{-1}$ )

The data pertaining to total phosphorus uptake ranged from 6.16 to 10.32  $\text{kg ha}^{-1}$  (Table 4.3). Significant difference was observed in respect of phosphorus uptake by seed and stover of soybean together with total uptake due to different sulphur level at 5 % level of probability. Maximum phosphorus uptake (7.15, 3.02 and 10.17  $\text{kg ha}^{-1}$  in seed, stover and total respectively) was associated with 30  $\text{kg S ha}^{-1}$  and it was closely followed by 45  $\text{kg S ha}^{-1}$  (6.49, 2.92 and 9.42  $\text{kg ha}^{-1}$  in seed, stover and total respectively). Phosphorus uptake in these two treatments was statistically at par with each other.

Maximum total phosphorus uptake (9.10  $\text{kg ha}^{-1}$ ) was obtained with 1.0  $\text{kg B ha}^{-1}$  followed by 1.5  $\text{kg B ha}^{-1}$  (9.01  $\text{kg ha}^{-1}$ ) and 0.5  $\text{kg B ha}^{-1}$  (8.56  $\text{kg ha}^{-1}$ ). Phosphorus uptake in these plots was significantly higher than those of 0  $\text{kg B ha}^{-1}$  but statistically similar with each other.

Maximum phosphorus uptake by seed (7.43  $\text{kg ha}^{-1}$ ) was recorded with T<sub>10</sub> (S<sub>30</sub>B<sub>0.5</sub>). However maximum total phosphorus uptake (10.61  $\text{kg ha}^{-1}$ ) and maximum uptake by stover (3.43  $\text{kg ha}^{-1}$ ) was associated with T<sub>12</sub> (S<sub>30</sub>B<sub>1.5</sub>). But interaction effect between sulphur and boron level was found to be non-significant.

### 4.3.3 Potassium Uptake ( $\text{kg ha}^{-1}$ )

Data on potassium uptake by seed and stover of soybean together with total uptake is presented in Table 4.3 & Fig. 4.4 it was observed that potassium uptake by stover was more than that of potassium uptake by seed. Increase in sulphur level resulted in significantly higher potassium uptake by seed, stover and total uptake and maximum uptake (11.99, 27.62 and 39.61  $\text{kg ha}^{-1}$  in seed, stover and total respectively) was associated with 30  $\text{kg S ha}^{-1}$  and minimum uptake (80.12, 16.86 and 96.97  $\text{kg ha}^{-1}$  in seed, stover and total respectively) with the treatment where sulphur was not applied i.e. 0  $\text{kg S ha}^{-1}$

Increase in level of boron resulted in significantly increase in potassium uptake by seed and maximum uptake (10.93, 25.91 and 36.85  $\text{kg ha}^{-1}$  in seed, stover and total respectively) was observed application of 1.0  $\text{kg B ha}^{-1}$  followed by 1.5  $\text{kg B ha}^{-1}$  and 0.5  $\text{kg B ha}^{-1}$ .

Different sulphur and boron level had no significant effect on potassium uptake by soybean. Higher total potassium uptake ( $42.23 \text{ kg ha}^{-1}$ ) was observed with  $T_{11} (S_{30}B_{1.0})$  followed by  $T_{15} (S_{45}B_{105})$  and  $T_{12} (S_{30}B_{1.5})$ .

#### 4.3.4 Sulphur Uptake ( $\text{kg ha}^{-1}$ )

Total sulphur uptake ranged from  $4.94$  to  $8.94 \text{ kg ha}^{-1}$  (Table 4.3) significant difference was observed in sulphur uptake by seed and stover of soybean together with total uptake due to different sulphur level. Higher sulphur uptake ( $6.39$ ,  $1.96$  and  $8.35 \text{ kg ha}^{-1}$  in seed, stover and total respectively) was associated with  $30 \text{ kg S ha}^{-1}$  and it statistically at par with  $45 \text{ kg S ha}^{-1}$  ( $5.89$ ,  $1.94$  and  $7.83 \text{ kg ha}^{-1}$  in seed, stover and total respectively). Minimum total sulphur uptake ( $5.56 \text{ kg ha}^{-1}$ ) was observed with  $0 \text{ kg S ha}^{-1}$  and it was statistically lower than sulphur applied plots.

Statistically higher total sulphur uptake ( $7.74 \text{ kg ha}^{-1}$ ) was obtained with  $1.0 \text{ kg B ha}^{-1}$  followed by  $1.5 \text{ kg B ha}^{-1}$  ( $7.62 \text{ kg ha}^{-1}$ ) and  $0.5 \text{ kg B ha}^{-1}$  ( $7.05 \text{ kg ha}^{-1}$ ). However sulphur uptake in these treatments was statistically similar with each other.

Interaction between sulphur and boron level was found to have no significant effect on sulphur uptake and maximum total sulphur uptake ( $8.94 \text{ kg ha}^{-1}$ ) was recorded with  $T_{11} (S_{30}B_{1.0})$  presented Fig. 4.5

#### 4.3.5 Boron Uptake ( $\text{g ha}^{-1}$ )

Boron uptake by seed and stover of soybean along with total uptake is presented in Table 4.3 & Fig. 4.6 It was observed that boron uptake by stover was more than that of boron uptake by seed. Different sulphur level significantly

influenced boron uptake by seed, stover and total uptake and maximum uptake (73.89, 24.82 and 98.71 kg ha<sup>-1</sup> in seed, stover and total respectively) was associated with 30 kg S ha<sup>-1</sup> and minimum uptake (47.70, 17.00 and 64.70 kg ha<sup>-1</sup> in seed, stover and total respectively) with 0 kg S ha<sup>-1</sup>

Increase in boron level resulted in significantly higher boron uptake by seed, stover and total uptake. Maximum total uptake (90.08 kg ha<sup>-1</sup>) was observed with application of 1.0 kg B ha<sup>-1</sup> followed by 1.5 kg B ha<sup>-1</sup> (89.38 kg B ha<sup>-1</sup>)

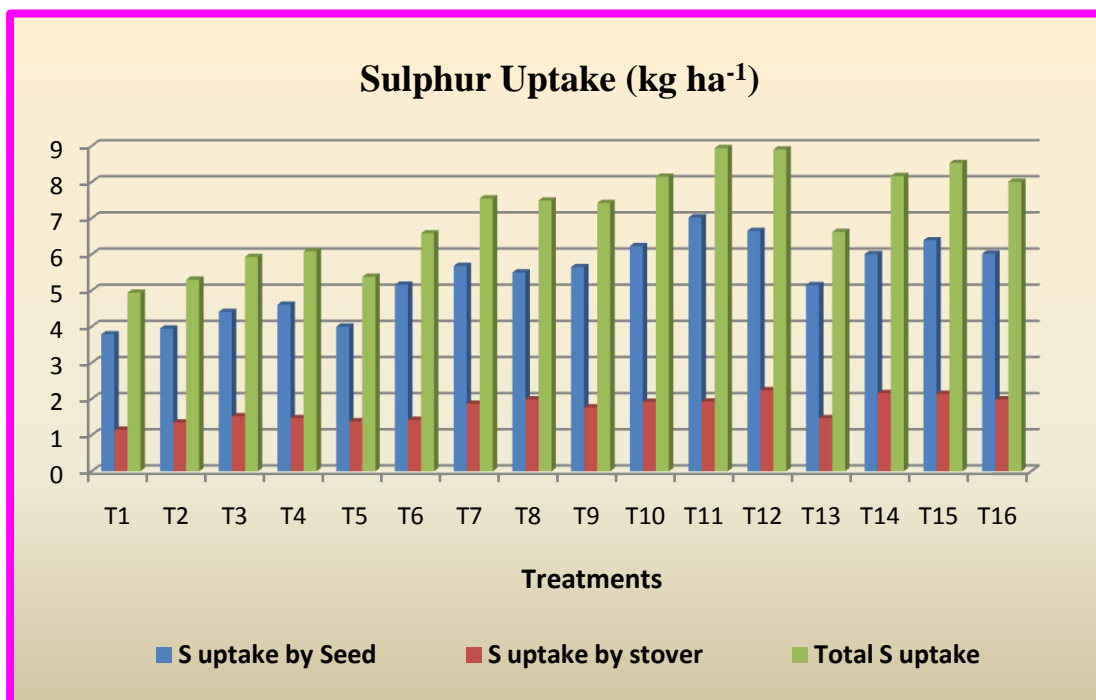
Interaction of sulphur and boron level had no significant effect on potassium boron uptake by soybean.

Results are in agreement with those of Ganeshamurthy (1996) who reported that sulphur significantly increased the S uptake. Similar result was found by Chand *et al.* (1997) in mustard.

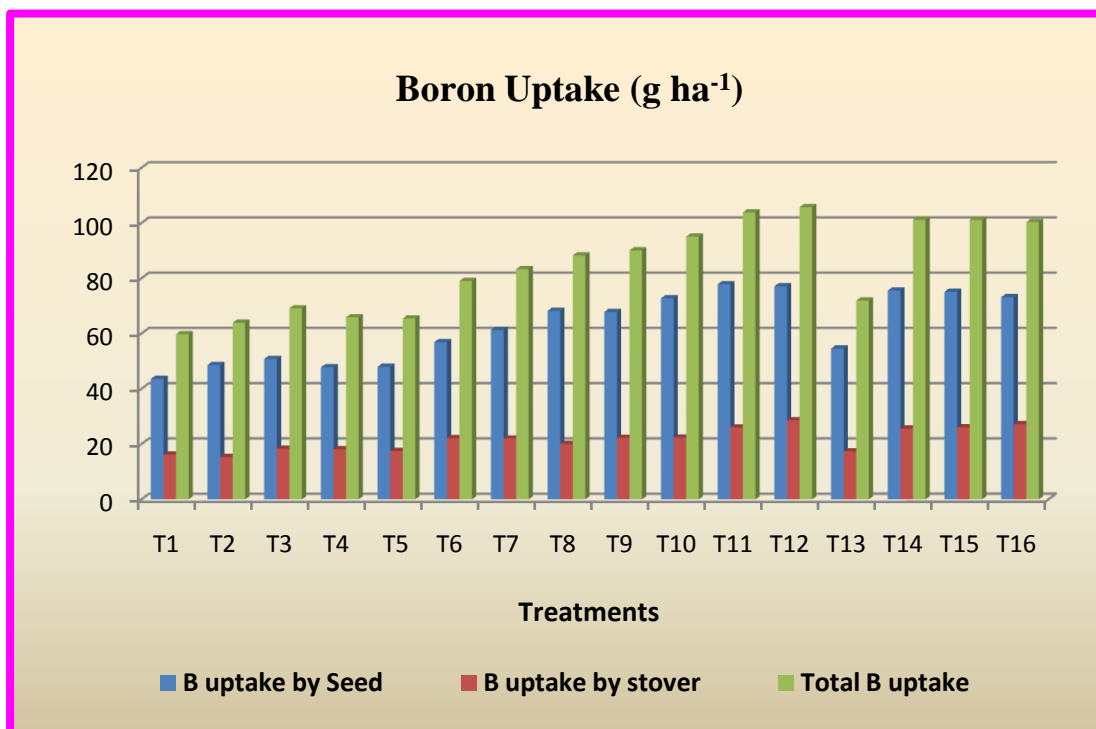
In this study it might be concluded that boron uptake was influence by B application, this probably due to the application of boron in the field and high grain yield. The results are in concurrent with the findings observed by Kumar *et al.* (1996) who reported that uptake of boron increased due to boron application.

**Table 4.4 Effect of sulphur and boron application on nutrient uptake by seed & stover of soybean**

Treatment	Sulphur Uptake (kg ha <sup>-1</sup> )			Boron Uptake (g ha <sup>-1</sup> )		
	Seed	Straw	Total	Seed	Straw	Total
T <sub>1</sub> - S <sub>0</sub> B <sub>0</sub>	3.79	1.15	4.94	43.59	16.19	59.78
T <sub>2</sub> - S <sub>0</sub> B <sub>0.5</sub>	3.95	1.35	5.30	48.62	15.34	63.95
T <sub>3</sub> - S <sub>0</sub> B <sub>1.0</sub>	4.41	1.52	5.93	50.82	18.33	69.15
T <sub>4</sub> - S <sub>0</sub> B <sub>1.5</sub>	4.61	1.47	6.08	47.78	18.12	65.90
T <sub>5</sub> - S <sub>15</sub> B <sub>0</sub>	4.00	1.38	5.38	47.98	17.50	65.48
T <sub>6</sub> - S <sub>15</sub> B <sub>0.5</sub>	5.16	1.42	6.58	56.88	22.15	79.03
T <sub>7</sub> - S <sub>15</sub> B <sub>1.0</sub>	5.68	1.87	7.55	61.33	22.00	83.33
T <sub>8</sub> - S <sub>15</sub> B <sub>1.5</sub>	5.50	1.99	7.49	68.23	20.06	88.29
T <sub>9</sub> - S <sub>30</sub> B <sub>0</sub>	5.65	1.77	7.42	67.84	22.26	90.10
T <sub>10</sub> - S <sub>30</sub> B <sub>0.5</sub>	6.23	1.92	8.15	72.78	22.33	95.12
T <sub>11</sub> - S <sub>30</sub> B <sub>1.0</sub>	7.02	1.93	8.94	77.85	26.02	103.88
T <sub>12</sub> - S <sub>30</sub> B <sub>1.5</sub>	6.65	2.24	8.90	77.10	28.66	105.76
T <sub>13</sub> - S <sub>45</sub> B <sub>0</sub>	5.15	1.47	6.62	54.60	17.36	71.96
T <sub>14</sub> - S <sub>45</sub> B <sub>0.5</sub>	6.01	2.16	8.17	75.57	25.61	101.18
T <sub>15</sub> - S <sub>45</sub> B <sub>1.0</sub>	6.39	2.14	8.53	75.09	26.06	101.14
T <sub>16</sub> - S <sub>45</sub> B <sub>1.5</sub>	6.02	1.99	8.01	73.17	27.20	100.38
<b>S levels (kg ha<sup>-1</sup>)</b>						
0	4.19	1.37	5.56	47.70	17.00	64.70
15	5.08	1.67	6.75	58.60	20.43	79.03
30	6.39	1.96	8.35	73.89	24.82	98.71
45	5.89	1.94	7.83	69.61	24.06	93.66
<b>B levels (kg ha<sup>-1</sup>)</b>						
0	4.65	1.44	6.09	53.50	18.33	71.83
0.5	5.34	1.71	7.05	63.46	21.36	84.82
1.0	5.88	1.86	7.74	66.27	23.10	89.38
1.5	5.70	1.92	7.62	66.57	23.51	90.08
<b>SEm±</b>						
S Level	0.264	0.092	0.333	2.828	1.290	3.498
B Level	0.264	0.092	0.333	2.828	1.290	3.498
(SXB) Interaction	0.528	0.184	0.666	5.656	2.581	6.997
<b>CD (P=0.05)</b>						
S Level	0.76	0.265	0.96	8.17	3.727	10.104
B Level	0.76	0.265	0.96	8.17	3.727	10.104
(SXB) Interaction	NS	NS	NS	NS	NS	NS



**Fig. 4.5 :**Effect of sulphur and boron on Sulphur uptake ( $\text{kg ha}^{-1}$ )



**Fig. 4.6:** Effect of sulphur and boron on Boron uptake ( $\text{g ha}^{-1}$ )

## 4.4 Effect of sulphur and boron on available nutrient status of post harvest soil

### 4.4.1 Available nitrogen ( $\text{kg ha}^{-1}$ )

Data on available nitrogen status is presented in Table 4.4 and Fig.4.7 the results clearly indicated that there was variation in available nitrogen status of soil. In all the treatments available nitrogen was increased over the initial value ( $225.45 \text{ kg ha}^{-1}$ ).

Increase in sulphur level up to  $30 \text{ kg ha}^{-1}$  resulted in increase in available nitrogen and thereafter it was decreased. Highest status was recorded with  $30 \text{ kg S ha}^{-1}$  ( $239.48 \text{ kg ha}^{-1}$ ) followed by  $45 \text{ kg S ha}^{-1}$  ( $237.13 \text{ kg ha}^{-1}$ ) and  $15 \text{ kg S ha}^{-1}$  ( $235.74 \text{ kg ha}^{-1}$ ). Minimum available nitrogen ( $234.79 \text{ kg ha}^{-1}$ ) was recorded with  $0 \text{ kg S ha}^{-1}$ .

Available nitrogen was recorded higher with  $1.5 \text{ kg B ha}^{-1}$  ( $238.84 \text{ kg ha}^{-1}$ ) followed by  $1.0 \text{ kg B ha}^{-1}$  ( $237.42 \text{ kg ha}^{-1}$ ) and  $0.5 \text{ kg B ha}^{-1}$  ( $236.68 \text{ kg ha}^{-1}$ ).

Sulphur and boron level and interaction between sulphur and boron level had no significant effect on available nitrogen.

Applications of sulphur have dissolution effect on soil phosphorus which in turn have increased nodulation and nitrogen fixation causing increased available nitrogen in soil. These finding was also supported by Suryanarayana Reddy and Chonkar (1991), Kumaran and Solaimalai (2000), Nayak *et al.* (2009) and Singh *et al.* (2011).

### 4.4.2 Available Phosphorus ( $\text{kg ha}^{-1}$ )

It is evident from the Table 4.4 & Fig. 4.8 that available phosphorus in post harvest soil ranged from  $10.65$  to  $12.15 \text{ kg ha}^{-1}$ . Available phosphorus in soil increased over the initial value ( $9.68 \text{ kg ha}^{-1}$ ). Different sulphur level significantly influenced available phosphorus in soil and highest value was observed with  $30 \text{ kg S ha}^{-1}$  ( $12.02 \text{ kg ha}^{-1}$ ) and lowest ( $10.70 \text{ kg ha}^{-1}$ ) with  $0 \text{ kg S ha}^{-1}$

Dhage *et al.* (2014) also observed increased available phosphorus with sulphur application. Acidity produced by applied sulphur together with acids through root exudates dissolves bound phosphorus of soil increasing its availability.

It is evident from the Table 4.4 that available phosphorus was increased with increase in boron level over control i.e. 0 kg B ha<sup>-1</sup>. However, available phosphorus did not vary significantly.

Interaction between sulphur and boron level was found to have no significant effect on available soil phosphorus. Highest value (12.23 kg ha<sup>-1</sup>) was recorded with T<sub>12</sub> (S<sub>30</sub>B<sub>1.5</sub>).

#### **4.4.3 Available Potassium (kg ha<sup>-1</sup>)**

Increase in level of sulphur caused decrease in available potassium (Table 4.5 & Fig. 4.9) over the initial value (474 kg ha<sup>-1</sup>). Highest available potassium (471.37 kg ha<sup>-1</sup>) was observed with 0 kg S ha<sup>-1</sup> and lowest (466.66 kg ha<sup>-1</sup>) with 30 kg S ha<sup>-1</sup>.

Different level of boron caused variation in available potassium and highest available potassium (473.79 kg ha<sup>-1</sup>) was observed with 0 kg B ha<sup>-1</sup> and lowest (463.38 kg ha<sup>-1</sup>) with 1.0 kg B ha<sup>-1</sup>.

Available potassium in soil ranged from 459.73 to 480.22 kg ha<sup>-1</sup> and maximum available potassium (480.22 kg ha<sup>-1</sup>) was observed with control i.e. in treatment where no sulphur and boron was added. Sulphur and boron level, interaction between sulphur and boron level was found to have no significant effect on available soil potassium.

#### **4.4.4 Available sulphur (kg ha<sup>-1</sup>)**

Data on available sulphur status is presented in Table 4.4 and Fig.4.10 The results clearly indicated that there was significant variation in available sulphur status of soil. In all the treatments available sulphur was increased over the initial value (22.15 kg ha<sup>-1</sup>). Increase in sulphur level resulted in increase in available sulphur and highest status (27.05 kg ha<sup>-1</sup>) was recorded with 45 kg S ha<sup>-1</sup> followed by 30 kg S ha<sup>-1</sup> (25.00 kg ha<sup>-1</sup>) and 15 kg S ha<sup>-1</sup> (23.02 kg ha<sup>-1</sup>). Minimum available sulphur (21.12 kg ha<sup>-1</sup>) was recorded with 0 kg S ha<sup>-1</sup>. Kothari and Jethra (2002) also reported that the available sulphur increased with increasing levels of sulphur application.

Available sulphur was recorded higher with 1.5 kg B ha<sup>-1</sup> (24.48 kg ha<sup>-1</sup>) and minimum with 0 kg B ha<sup>-1</sup> (23.28 kg ha<sup>-1</sup>)

Boron level and interaction between sulphur and boron did not have significant effect on available sulphur. Kothari and Jethra (2002) also reported that the available sulphur increased with increasing levels of sulphur application phosphorus application had no effect on the sulphur content of soil.

#### **4.4.5 Available boron (mg kg<sup>-1</sup>)**

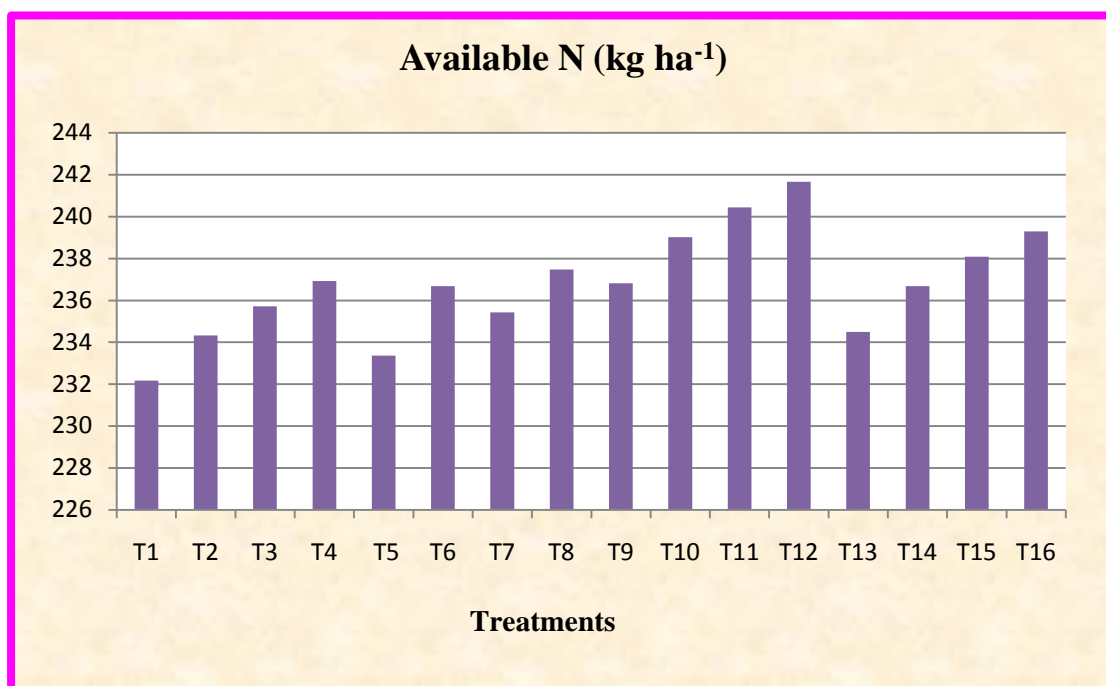
It is evident from the Table 4.4 & Fig. 4.11 that available boron in post harvest soil ranged from 0.83 to 1.25 mg kg<sup>-1</sup>. Available boron in soil increased over the initial value (0.88 mg kg<sup>-1</sup>). Different sulphur level influenced available boron in soil and highest value was observed with 45 kg S ha<sup>-1</sup> (1.08 mg kg<sup>-1</sup>) and lowest (0.92 mg kg<sup>-1</sup>) with 0 kg S ha<sup>-1</sup>. However, the difference was non-significant.

Available boron was increased with increase in boron level over control i.e. 0 kg B ha<sup>-1</sup> and highest value was (1.17 mg kg<sup>-1</sup>) seen with 1.5 kg B ha<sup>-1</sup> and it was statistically significant.

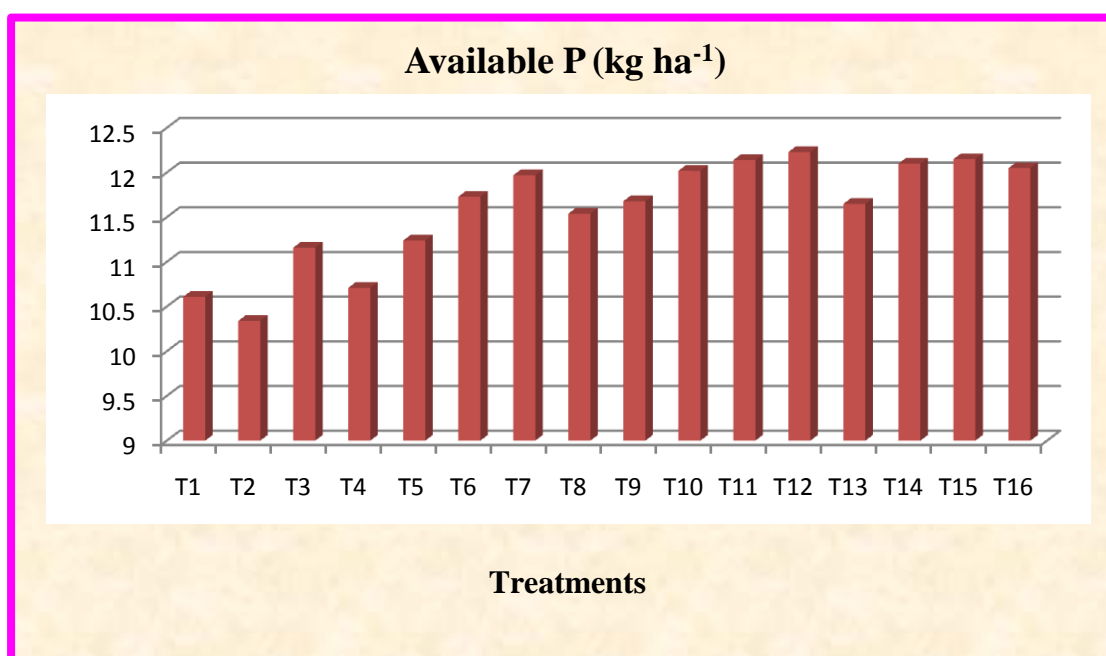
Interaction between sulphur and boron level was found to have no significant effect on available soil boron. Highest value (1.30 mg ha<sup>-1</sup>) was recorded with T<sub>8</sub> (S<sub>15</sub>B<sub>1.5</sub>). Konthoujam Nandini Devi, 2012 also observed similar results

**Table 4.5 : Effect of sulphur and boron on available nutrient status of post harvest soil**

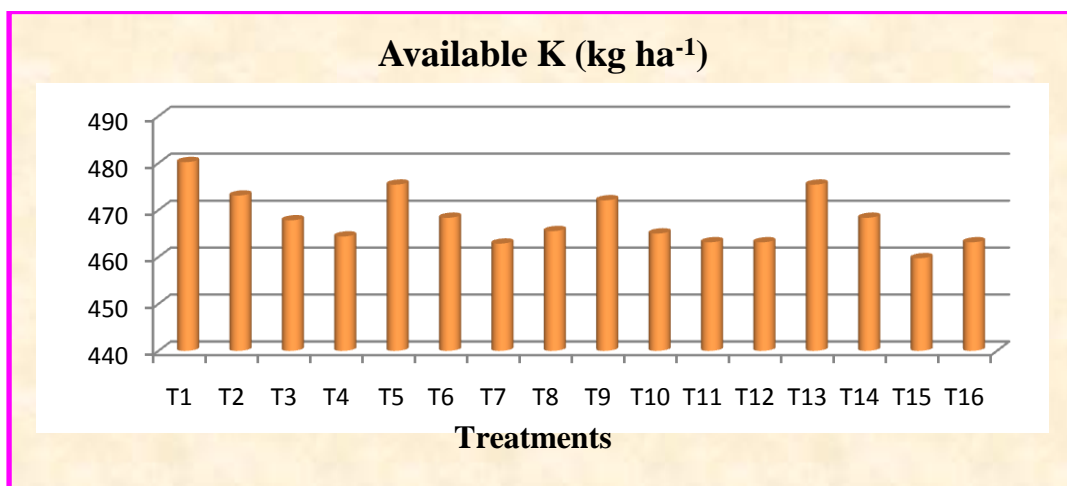
<b>Treatment</b>	<b>Available N (kg ha<sup>-1</sup>)</b>	<b>Available P (kg ha<sup>-1</sup>)</b>	<b>Available K (kg ha<sup>-1</sup>)</b>	<b>Available S (kg ha<sup>-1</sup>)</b>	<b>Available B (mg kg<sup>-1</sup>)</b>
T <sub>1</sub> - S <sub>0</sub> B <sub>0</sub>	232.17	10.61	480.22	20.62	0.83
T <sub>2</sub> - S <sub>0</sub> B <sub>0.5</sub>	234.33	10.34	473.09	20.92	0.89
T <sub>3</sub> - S <sub>0</sub> B <sub>1.0</sub>	235.72	11.16	467.81	21.37	0.99
T <sub>4</sub> - S <sub>0</sub> B <sub>1.5</sub>	236.92	10.71	464.37	21.56	1.00
T <sub>5</sub> - S <sub>15</sub> B <sub>0</sub>	233.37	11.24	475.42	22.27	0.86
T <sub>6</sub> - S <sub>15</sub> B <sub>0.5</sub>	236.68	11.73	468.36	22.57	0.95
T <sub>7</sub> - S <sub>15</sub> B <sub>1.0</sub>	235.43	11.97	462.85	24.02	0.91
T <sub>8</sub> - S <sub>15</sub> B <sub>1.5</sub>	237.48	11.54	465.52	23.21	1.30
T <sub>9</sub> - S <sub>30</sub> B <sub>0</sub>	236.82	11.68	472.08	24.42	0.83
T <sub>10</sub> - S <sub>30</sub> B <sub>0.5</sub>	239.02	12.02	465.01	25.36	1.00
T <sub>11</sub> - S <sub>30</sub> B <sub>1.0</sub>	240.44	12.14	463.13	24.84	1.25
T <sub>12</sub> - S <sub>30</sub> B <sub>1.5</sub>	241.66	12.23	463.13	25.38	1.19
T <sub>13</sub> - S <sub>45</sub> B <sub>0</sub>	234.49	11.65	475.42	25.80	0.86
T <sub>14</sub> - S <sub>45</sub> B <sub>0.5</sub>	236.68	12.10	468.36	27.10	1.10
T <sub>15</sub> - S <sub>45</sub> B <sub>1.0</sub>	238.08	12.15	459.73	27.55	1.18
T <sub>16</sub> - S <sub>45</sub> B <sub>1.5</sub>	239.29	12.05	463.13	27.74	1.20
<b>S levels</b>					
0	234.79	10.70	471.37	21.12	0.92
15	235.74	11.62	468.04	23.02	1.00
30	239.48	12.02	465.84	25.00	1.06
45	237.13	11.99	466.66	27.05	1.08
<b>B levels</b>					
0	234.21	11.30	473.79	23.28	0.85
0.5	236.68	11.55	468.70	23.99	0.99
1.0	237.42	11.85	463.38	24.44	1.08
1.5	238.84	11.63	464.04	24.48	1.17
<b>SEm±</b>					
S levels	1.61	0.35	4.426	0.563	0.045
B levels	1.61	0.35	4.426	0.563	0.045
(S x B)	3.22	0.69	8.853	1.126	0.090
<b>Interaction</b>					
<b>CD (P=0.05)</b>					
S levels	NS	1.00	NS	1.63	NS
B levels	NS	NS	NS	NS	0.13
(SXB)	NS	NS	NS	NS	NS
<b>Interaction</b>					
<b>Initial Value</b>	<b>225</b>	<b>9.68</b>	<b>474</b>	<b>22.15</b>	<b>0.88</b>



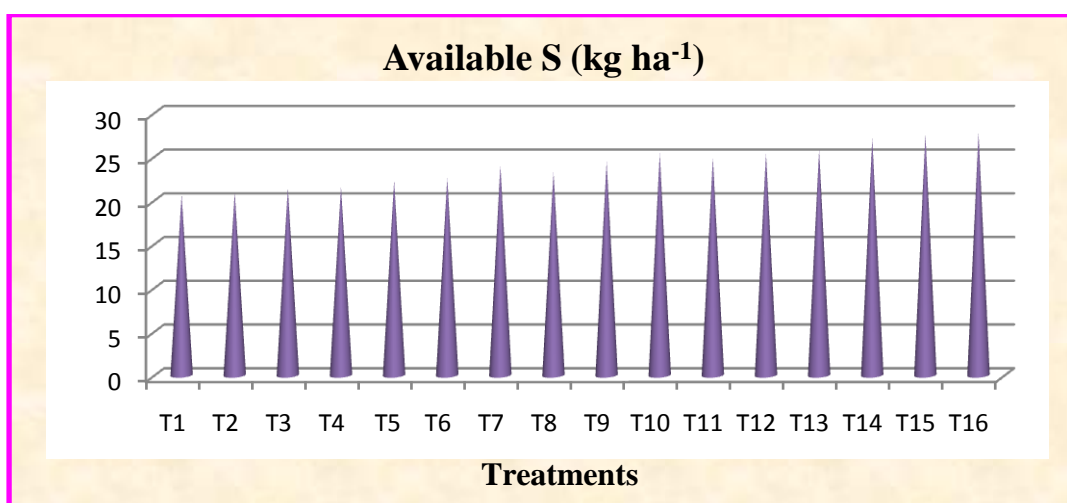
**Fig. 4.7: Effect of sulphur and boron on available nitrogen (kg ha<sup>-1</sup>)**



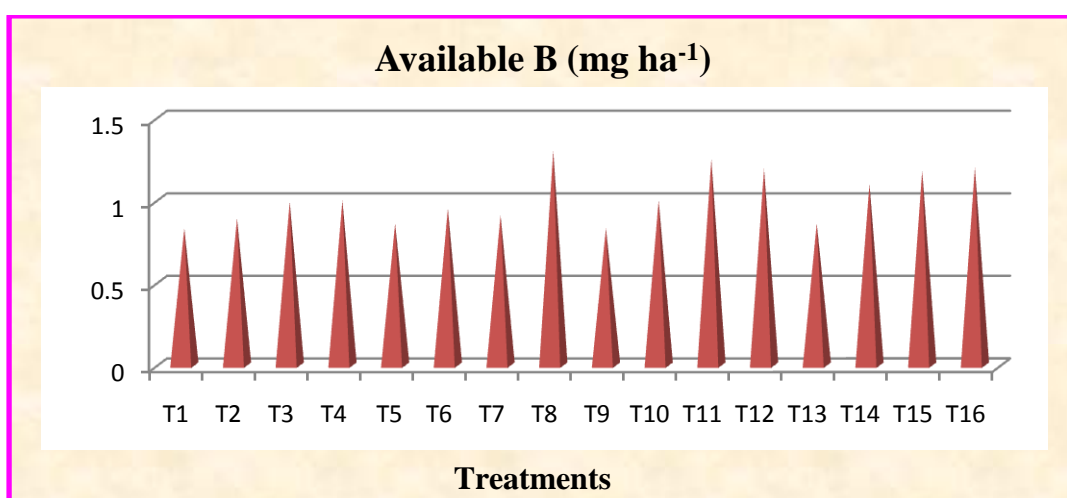
**Fig. 4.8: Effect of sulphur and boron on available phosphorus (kg ha<sup>-1</sup>)**



**Fig. 4.9** :Effect of sulphur and boron on available potassium (kg ha<sup>-1</sup>)



**Fig. 4.10** :Effect of sulphur and boron on available sulphur (kg ha<sup>-1</sup>)



**Fig. 4.11** :Effect of sulphur and boron on available Boron (mg ha<sup>-1</sup>)

## CHAPTER-V

### SUMMARY AND CONCLUSIONS

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The present investigation entitled “**Influence of Sulphur and Boron on yield of Soybean (*Glycine max*) in Vertisols of Kabirdham District**” was conducted at Krishi Vigyan Kendra, Kawardha farm; Kabirdham (C.G.) during *kharif* season 2014 to determine the effect of sulphur and boron application on growth and yield of soybean, uptake of nitrogen, phosphorus, potassium, sulphur and boron by soybean and available nutrient status on post harvest soil. The salient findings of the present study are as follows.

#### **Growth and Yield Parameters**

Plant height, pods plant<sup>-1</sup>, 100 seed weight, seed yield, stover yield and harvest index were recorded under growth and yield attributing parameters. Plant height of soybean ranged from 35.43 to 43.90 cm. Application of sulphur significantly affected plant height and maximum height (42.89 cm) was observed with application of 45 kg S ha<sup>-1</sup> followed by 30 kg S ha<sup>-1</sup> (41.63 cm). Boron levels and interaction of sulphur and boron level had no significant effect on plant height. Number of pods plant<sup>-1</sup> was observed significantly higher with application of different sulphur levels and maximum number (48.83) was observed with 45 kg S ha<sup>-1</sup> and minimum (44.33) with 0 kg S ha<sup>-1</sup>. Maximum number of pods plant<sup>-1</sup> (47.17) was recorded due to application of 1.5 kg B ha<sup>-1</sup> followed by 1.0 kg B ha<sup>-1</sup> (46.92). However, number of pods plant<sup>-1</sup> under different boron levels and interaction of sulphur and boron level did not have any significant effect on the number of pods plant<sup>-1</sup>. Highest weight of 100 seed (12.32 g) was found with application of 30 kg S ha<sup>-1</sup> and the lowest weight (10.55 g) was associated with 0 kg S ha<sup>-1</sup>. Boron level had significant effect on 100 seed weight and the same was increased with increase in boron level up to 1.0 kg B ha<sup>-1</sup> and beyond this level 100 seed weight was decreased. Interaction of sulphur and boron level did not have any significant effect on 100 seed weight and highest 100 seed weight (12.92 g) was observed with T<sub>11</sub> (S<sub>30</sub>B<sub>1.0</sub>). Seed and stover yield of

soybean ranged from 13.72 to 21.83 q ha<sup>-1</sup> and 15.57 to 23.26 q ha<sup>-1</sup> respectively. Significant difference was observed in respect of seed and stover yield with different sulphur and boron level at 5 % level of probability. Maximum seed yield (21.04 q ha<sup>-1</sup>) and stover yield (22.55 q ha<sup>-1</sup>) was recorded with 30 kg S ha<sup>-1</sup>. The second highest seed yield (19.67 q ha<sup>-1</sup>) and stover yield (22.20 q ha<sup>-1</sup>) was obtained from 45 kg S ha<sup>-1</sup>. Seed and stover yield of soybean was significantly influenced by boron level. Significantly higher seed yield (18.82 q ha<sup>-1</sup>) and stover yield (21.05 q ha<sup>-1</sup>) was observed with 1.0 kg B ha<sup>-1</sup> followed by 1.5 kg B ha<sup>-1</sup> (18.71 q ha<sup>-1</sup> and 20.88 q ha<sup>-1</sup> seed and stover yield respectively). Interaction effect of sulphur and boron level was found to be non-significant in relation to seed and stover yield. Sulphur and boron levels and their interactions did not result any significant variations in harvest index. Highest harvest indices were associated with 30 kg S ha<sup>-1</sup> (48.25 %), 0.5 kg B ha<sup>-1</sup> (47.49 %) and T<sub>10</sub> - S<sub>30</sub>B<sub>0.5</sub> (48.94 %).

#### **Effect of sulphur and boron on nutrient content of soybean**

Nitrogen, phosphorus, potassium, sulphur and boron content in seed and stover of soybean were determined by standard procedures. Nutrient content was non significantly affected by sulphur and boron levels and their interactions. Nitrogen, phosphorus, sulphur and boron content were found more in seed in comparison to stover. In contrast potassium content was observed more in stover than seed. Maximum nitrogen, phosphorus, potassium and boron content (5.81 and 1.10 %, 0.34 and 0.125 %, 0.57 and 1.22 %, 35.19 and 10.93 % in seed and stover respectively) were associated with application of 30 kg S ha<sup>-1</sup>. No difference in sulphur content (0.30 and 0.09 % in seed and stover respectively) were observed with application of different sulphur level but was higher than that of control i.e. 0 kg S ha<sup>-1</sup> (0.29 and 0.08 % in seed and stover respectively). Application of 1.5 kg B ha<sup>-1</sup> recorded maximum boron content (35.45 and 11.21 mg kg<sup>-1</sup> in seed and stover respectively). Nitrogen, phosphorus, potassium and sulphur content was found maximum (5.75 and 1.10 %, 0.33 and 0.134 %, 0.58 and 1.22 %, 0.31 and 0.93 % in seed and stover respectively) with application of 1.0 kg B ha<sup>-1</sup>.

Sulphur content with application of  $1.5 \text{ kg B ha}^{-1}$  was similar to that of  $1.0 \text{ kg B ha}^{-1}$ .

### **Effect of sulphur and boron on nutrient uptake by soybean**

Application of different sulphur level significantly influenced the nitrogen uptake by seed, stover and total uptake and maximum uptake ( $122.17$ ,  $24.86$  and  $147.03 \text{ kg ha}^{-1}$  in seed, stover and total respectively) was associated with  $30 \text{ kg S ha}^{-1}$  and minimum uptake ( $80.12$ ,  $16.86$  and  $96.97 \text{ kg ha}^{-1}$  in seed, stover and total respectively) with the treatment where sulphur was not applied i.e.  $0 \text{ kg S ha}^{-1}$ . Increase in level of boron resulted in significantly increase in nitrogen uptake by seed and maximum uptake ( $108.36$ ,  $23.15$  and  $131.51 \text{ kg ha}^{-1}$  in seed, stover and total respectively) was observed with  $1.0 \text{ kg B ha}^{-1}$  while minimum in plot where boron was not applied ( $0 \text{ kg B ha}^{-1}$ ). Nitrogen uptake with  $1.5 \text{ kg B ha}^{-1}$  and  $1.0 \text{ kg B ha}^{-1}$  were statistically at par with each other but significantly higher over control i.e.  $0 \text{ kg B ha}^{-1}$ . Nitrogen uptake by soybean was not significantly affected by interaction of sulphur and boron level. Significant difference was observed in respect of phosphorus uptake due to different sulphur level. Maximum total phosphorus uptake ( $10.17 \text{ kg ha}^{-1}$ ) was associated with  $30 \text{ kg S ha}^{-1}$  and it was closely followed by  $45 \text{ kg S ha}^{-1}$  ( $9.42 \text{ kg ha}^{-1}$ ). Phosphorus uptake in these sulphur levels were statistically at par with each other. Maximum total phosphorus uptake ( $9.10 \text{ kg ha}^{-1}$ ) was obtained with  $1.0 \text{ kg B ha}^{-1}$  followed by  $1.5 \text{ kg B ha}^{-1}$  ( $9.01 \text{ kg ha}^{-1}$ ) and  $0.5 \text{ kg B ha}^{-1}$  ( $8.56 \text{ kg ha}^{-1}$ ). Phosphorus uptake in these plots was significantly higher than those of  $0 \text{ kg B ha}^{-1}$  but statistically similar with each other. Interaction effect between sulphur and boron level was found to be non-significant maximum total phosphorus uptake ( $10.61 \text{ kg ha}^{-1}$ ) being associated with  $T_{12} (S_{30}B_{1.5})$ . Potassium uptake was found more in stover than seed of soybean. Increase in sulphur level resulted in significantly higher potassium uptake and maximum total uptake ( $39.61 \text{ kg ha}^{-1}$ ) was associated with  $30 \text{ kg S ha}^{-1}$  and minimum uptake ( $96.97 \text{ kg ha}^{-1}$ ) with the treatment where sulphur was not applied ( $0 \text{ kg S ha}^{-1}$ ). Maximum total potassium uptake ( $36.85 \text{ kg ha}^{-1}$ ) was observed with application of  $1.0 \text{ kg B ha}^{-1}$  followed by  $1.5 \text{ kg B ha}^{-1}$  and  $0.5 \text{ kg B ha}^{-1}$ . Different

sulphur and boron level had no significant effect on potassium uptake. Significant difference was observed in sulphur uptake by soybean due to different sulphur levels and highest total sulphur uptake ( $8.35 \text{ kg ha}^{-1}$ ) was associated with  $30 \text{ kg S ha}^{-1}$  and it was statistically at par with  $45 \text{ kg S ha}^{-1}$  ( $7.83 \text{ kg ha}^{-1}$ ). Statistically higher total sulphur uptake over control was obtained with  $1.0 \text{ kg B ha}^{-1}$  ( $7.74 \text{ kg ha}^{-1}$ ) followed by  $1.5 \text{ kg B ha}^{-1}$  ( $7.62 \text{ kg ha}^{-1}$ ) and  $0.5 \text{ kg B ha}^{-1}$  ( $7.05 \text{ kg ha}^{-1}$ ). However sulphur uptake in these treatments was statistically similar with each other. Interaction between sulphur and boron level was found to have no significant effect on sulphur uptake. Boron uptake by seed was more than that of boron uptake by stover. Different sulphur level significantly influenced boron uptake maximum total uptake ( $98.71 \text{ g ha}^{-1}$ ) was associated with  $30 \text{ kg S ha}^{-1}$  and minimum uptake ( $64.70 \text{ g ha}^{-1}$ ) with  $0 \text{ kg S ha}^{-1}$ . Maximum total uptake ( $90.08 \text{ g ha}^{-1}$ ) was observed with application of  $1.0 \text{ kg B ha}^{-1}$  followed by  $1.5 \text{ kg B ha}^{-1}$  ( $89.38 \text{ g ha}^{-1}$ ). Interaction of sulphur and boron level had no significant effect on boron uptake by soybean.

#### **Effect of sulphur and boron on available nutrient status of post harvest soil**

Available nitrogen in post harvest soil was increased over the initial value ( $225.45 \text{ kg ha}^{-1}$ ) in all the treatments. Increase in sulphur level up to  $30 \text{ kg ha}^{-1}$  resulted in increase in available nitrogen and thereafter it was decreased. Highest status was recorded with  $30 \text{ kg S ha}^{-1}$  ( $239.48 \text{ kg ha}^{-1}$ ) followed by  $45 \text{ kg S ha}^{-1}$  ( $237.13 \text{ kg ha}^{-1}$ ) and  $15 \text{ kg S ha}^{-1}$  ( $235.74 \text{ kg ha}^{-1}$ ). Available nitrogen was recorded higher with  $1.5 \text{ kg B ha}^{-1}$  ( $238.84 \text{ kg ha}^{-1}$ ) followed by  $1.0 \text{ kg B ha}^{-1}$  ( $237.42 \text{ kg ha}^{-1}$ ) and  $0.5 \text{ kg B ha}^{-1}$  ( $236.68 \text{ kg ha}^{-1}$ ). Available phosphorus in post harvest soil increased over the initial value ( $9.68 \text{ kg ha}^{-1}$ ). Different sulphur level significantly influenced available phosphorus in soil and highest value was observed with  $30 \text{ kg S ha}^{-1}$  ( $12.02 \text{ kg ha}^{-1}$ ) and lowest ( $10.70 \text{ kg ha}^{-1}$ ) with  $0 \text{ kg S ha}^{-1}$ . Available phosphorus was increased with increase in boron level over control ( $0 \text{ kg B ha}^{-1}$ ) but did not vary significantly. Different boron and sulphur levels did not have significant effect on available potassium. Increase in level of sulphur and boron caused decrease in available potassium over the initial value ( $474 \text{ kg ha}^{-1}$ ). Highest available potassium ( $471.37 \text{ kg ha}^{-1}$ ) was observed with  $0 \text{ kg S ha}^{-1}$  and

lowest ( $466.66 \text{ kg ha}^{-1}$ ) with  $30 \text{ kg S ha}^{-1}$ . Similarly highest available potassium ( $473.79 \text{ kg ha}^{-1}$ ) was observed with  $0 \text{ kg B ha}^{-1}$  and lowest ( $463.38 \text{ kg ha}^{-1}$ ) with  $1.0 \text{ kg B ha}^{-1}$ . In all the treatments available sulphur was increased over the initial value ( $22.15 \text{ kg ha}^{-1}$ ). Increase in sulphur level resulted in increase in available sulphur and highest status ( $27.05 \text{ kg ha}^{-1}$ ) was recorded with  $45 \text{ kg S ha}^{-1}$  followed by  $30 \text{ kg S ha}^{-1}$  ( $25.00 \text{ kg ha}^{-1}$ ) and  $15 \text{ kg S ha}^{-1}$  ( $23.02 \text{ kg ha}^{-1}$ ). Available sulphur was recorded highest with  $1.5 \text{ kg B ha}^{-1}$  ( $24.48 \text{ kg ha}^{-1}$ ) and minimum with  $0 \text{ kg B ha}^{-1}$  ( $23.28 \text{ kg ha}^{-1}$ ). Available boron in soil increased over the initial value ( $0.88 \text{ mg kg}^{-1}$ ). Different sulphur level influenced available boron in soil and highest value was observed with  $45 \text{ kg S ha}^{-1}$  ( $1.08 \text{ mg kg}^{-1}$ ) and lowest ( $0.92 \text{ mg kg}^{-1}$ ) with  $0 \text{ kg S ha}^{-1}$ . Available boron was increased with increase in boron level over control i.e. ( $0 \text{ kg B ha}^{-1}$ ) and highest value ( $1.17 \text{ mg kg}^{-1}$ ) was seen with  $1.5 \text{ kg B ha}^{-1}$  and it was statistically significant. Interaction between sulphur and boron levels was found to have no significant effect on available nitrogen, phosphorus, potassium, sulphur and boron in post harvest soil.

## CONCLUSIONS

In the light of study conducted on “Influence of Sulphur and Boron on yield of Soybean (*Glycine max*) in Vertisols of Kabirdham District”, it can be concluded that yield attributes and yield of soybean was significantly influenced by different sulphur levels and the dose of  $30 \text{ kg S ha}^{-1}$  was found optimum for getting maximum yield of soybean. Among boron levels,  $1.0 \text{ kg B ha}^{-1}$  was superior to others for getting higher soybean yield. Same levels of sulphur and boron ( $30 \text{ kg S ha}^{-1}$  and  $1.0 \text{ kg B ha}^{-1}$ ) were superior over other levels in increasing the uptake of nitrogen, phosphorus, potassium, sulphur and boron by soybean. Available nitrogen, phosphorus and potassium in post harvest soil were found higher with  $30 \text{ kg S ha}^{-1}$  and  $1.0 \text{ kg B ha}^{-1}$ . However, available sulphur was more in treatment where sulphur was applied at higher level ( $45 \text{ kg S ha}^{-1}$ ) and similarly available boron was found more where higher level of boron was applied ( $1.5 \text{ kg B ha}^{-1}$ ). Interaction of sulphur and boron levels had no significant effect on different parameters that was studied.

## **SUGGESTIONS FOR FUTURE RESEARCH WORK**

In view of the above discussion the attention should be drawn towards following priority areas of research.

- Sulphur is important for oilseed crops and studies on the effect of sulphur on oilseed crops other than soybean of Kabirdham district should be studied.
- The study was conducted at farm of Krishi Vigyan Kendra, Kawardha. The same experiment should be replicated in farmers' field to draw more conclusions.
- Soybean is a legume crop and it involves in nitrogen fixation. So, experiment on the effect of molybdenum on soybean should also be carried out.
- The present investigation was limited to observe the effect of sulphur and boron on yield attributes and yield of soybean. The same may be extended to study the effect on quality parameters of soybean.

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## APPENDICES

### APPENDIX-A

Average value of available Nitrogen, Phosphorous and Potassium after harvest of soybean

Treatments	Available N (kg ha <sup>-1</sup> )	Available N (kg ha <sup>-1</sup> )	Available N (kg ha <sup>-1</sup> )
T <sub>1</sub> -S <sub>0</sub> B <sub>0</sub>	232.17	10.61	480.22
T <sub>2</sub> -S <sub>0</sub> B <sub>0.5</sub>	234.33	10.34	473.09
T <sub>3</sub> -S <sub>0</sub> B <sub>1.0</sub>	235.72	11.16	467.81
T <sub>4</sub> -S <sub>0</sub> B <sub>1.5</sub>	236.92	10.71	464.37
T <sub>5</sub> -S <sub>15</sub> B <sub>0</sub>	233.37	11.24	475.42
T <sub>6</sub> -S <sub>15</sub> B <sub>0.5</sub>	236.68	11.73	468.36
T <sub>7</sub> -S <sub>15</sub> B <sub>1.0</sub>	235.43	11.97	462.85
T <sub>8</sub> -S <sub>15</sub> B <sub>1.5</sub>	237.48	11.54	465.52
T <sub>9</sub> -S <sub>30</sub> B <sub>0</sub>	236.82	11.68	472.08
T <sub>10</sub> -S <sub>30</sub> B <sub>0.5</sub>	239.02	12.02	465.01
T <sub>11</sub> -S <sub>30</sub> B <sub>1.0</sub>	240.44	12.14	463.13
T <sub>12</sub> -S <sub>30</sub> B <sub>1.5</sub>	241.66	12.23	463.13
T <sub>13</sub> -S <sub>45</sub> B <sub>0</sub>	234.49	11.65	475.42
T <sub>14</sub> -S <sub>45</sub> B <sub>0.5</sub>	236.68	12.10	468.36
T <sub>15</sub> -S <sub>45</sub> B <sub>1.0</sub>	238.08	12.15	459.73
T <sub>16</sub> -S <sub>45</sub> B <sub>1.5</sub>	239.29	12.05	463.13

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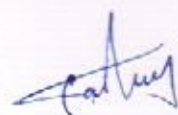
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