EFFECT OF SULPHUR, BORON, AND PHOSPHORUS SOLUBILIZING BIOFERTILIZER ON SOYBEAN (*Glycine max* L. Merril) UNDER FOOTHILL CONDITION OF NAGALAND

Thesis

submitted to

NAGALAND UNIVERSITY

in partial fulfillment of requirements for the Degree

of

Doctor of Philosophy

in

Agricultural Chemistry and Soil Science

by

KEVINEITUO BIER
Admn. No. Ph – 157/14 Regn. No. 764/2017

Department of Agricultural Chemistry and Soil Science
School of Agricultural Sciences and Rural Development,
Nagaland University, Medziphema Campus – 797 106
Nagaland
2021

DECLARATION

I, Mr. Kevineituo Bier, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other university/institute.

This is being submitted to Nagaland University for the degree of Doctor of Philosophy in Agricultural chemistry and Soil Science.

Date:

Place: **(KEVINEITUO BIER)**

………………………………..

Supervisor

NAGALAND UNIVERSITY
Medziphema Campus
School of Agricultural Sciences and Rural Development
Medziphema – 797106, Nagaland

Dr. P. K. Singh
Professor
Department of Agricultural Chemistry and Soil Science

CERTIFICATE – I

This is to certify that the thesis entitled "Effect of Sulphur, Boron, and Phosphorus Solubilizing Biofertilizer on Soybean (*Glycine max* L. Merril) Under Foothill Condition of Nagaland" submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy (Agriculture) in Agricultural Chemistry and Soil Science is the record of research work carried out by Mr. Kevineituo Bier, Registration No. 764/2017 under my personal supervision and guidance.

The results of the investigation reported in the thesis have not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

Date :
Place :

(Dr. P. K. Singh)
Supervisor

NAGALAND UNIVERSITY
Medziphema Campus
School of Agricultural Sciences and Rural Development
Medziphema – 797106, Nagaland

CERTIFICATE – II

VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN AGRICULTURAL CHEMISTRY AND SOIL SCIENCE

This is to certify that the thesis entitled "Effect of Sulphur, Boron, and Phosphorus Solubilizing Biofertilizer on Soybean (*Glycine max* L. Merril) Under Foothill Condition of Nagaland" submitted by Mr. Kevineituo Bier, Admission No. Ph-157/14, Registration No. 764/2017 to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Agricultural Chemistry and Soil Science has been examined by the Advisory Board and External examiner on ………………............

The performance of the student has been found Satisfactory/Unsatisfactory.

Member	Signature
1. ………………………………… (Supervisor & Chairman)	………………………….
2. ………………………………… (External examiner)	………………………….
3. …………………………………	………………………….
4. …………………………………	………………………….
5. …………………………………	………………………….
6. …………………………………	………………………….

Head
Dept. of Agril. Chemistry & Soil Science

Dean
School of Agricultural Sciences and Rural Development

ACKNOWLEDGEMENT

First and foremost, I thank the almighty God for showering His blessings and wisdom upon me throughout my research work and making me complete this thesis in good health.

This thesis would not have seen the light of day without the help and support of the people who have been instrumental in the completion of my thesis.

I would like to express my sincere gratitude to my advisor Prof. P.K. Singh, Department of Agricultural Chemistry and Soil Science, SASRD, Nagaland University for his continuous support, help, time, energy and constructive criticism throughout the investigation. He supervised the work with keen interest, provided most valuable, productive suggestions and sound advice at all stages of my work. I could not have imagined having a better advisor and mentor for my study.

My sincere acknowledgement to Prof. Aleminla Ao, Pro VC, NU SASRD, Medziphema and Prof. Akali Sema, Dean, NU SASRD, Medziphema for the timely help rendered whenever needed.

I am extremely grateful to Prof. A. K. Singh, HOD, Department of Agricultural Chemistry and Soil Science and my advisory committee Prof. S. K. Sharma, Prof. A K Singh, Department of Agricultural Chemistry and Soil Science, Prof. L. T. Longkumer, Department of Agronomy and, Prof. Amod Sharma, Department of Agricultural Economics for their sincere help and encouragement during the course of my research work. They have provided insight and direction right up to the end, which is greatly appreciated.

I would also like to thank Miss Areno Morr, STA and the non-teaching staffs of the Department of Agricultural Chemistry and Soil Science for offering all possible assistance and co-operation throughout my research work. I am thankful to Mr. Mhonbemo Ngullie, Assistant Librarian and his staff for providing all the necessary assistance and help for the success of my study.

I place my deep acknowledgement to Dr. A. K. Sahu and Dr. Dametre Lytan for their enourmous help in statistical data analysis.

Special thanks goes out to my friends, Waluniba, Vibeilie, Toshi, Along, Vilakuo and Merasenla. All the helping hands and the valuable time that you have rendered will always be remembered. I will forever be indebted to you all.

My utmost gratitude to my beloved parents and family members for their constant support and prayers throughout my study and enabling me to attain this position in my career.

Place :

Date : *(KEVINEITUO BIER)*

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

@	-	at a rate of
AM	-	Arbuscular Mycorrhizal
cm	-	Centimetre
CD	-	Critical Difference
B	-	Boron
BUE	-	Boron Use Efficiency
DAS	-	Days after Sowing
C	-	Carbon
ºC	-	Degree Celsius
Ca^{2+}	-	Calcium
CEC	-	Cation Exchange Capacity
Cmol	-	Centimol
dsm^{-1}	-	Decisiemens per meter
E	-	East
EC	-	Electrical conductivity
et al.	-	*et allia* (and others/co-workers)
Fig.	-	Figure
FYM	-	Farm Yard Manure
g	-	Gram
ha	-	Hectare
HI	-	Harvest index
hr	-	Hour
ICAR	-	Indian Council of Agricultural Research
i.e.	-	Id est (that is)
K	-	Potassium
kg	-	Kilogram
m	-	Metre
Mg	-	Magnesium
mg	-	Milligram
N_2	-	Dinitrogen
N	-	North

N	-	Nitrogen
NS	-	Non-significant
NU	-	Nagaland University
No.	-	Number
OC	-	Organic carbon
%	-	Per cent
P	-	Phosphorus
PSB	-	Phosphate Solubilizing Bacteria
PSM	-	Phosphate Solubilizing Microorganism
q	-	Quintal
RDF	-	Recommended Dose of Fertilizers
SASRD	-	School of Agricultural Sciences and Rural Development
Sl. No.	-	Serial number
spp.	-	Species
S	-	Sulphur
SEm±	-	Standard error of mean
t	-	Tonne
USDA	-	United States Department of Agriculture
Viz.	-	Namely
Zn	-	Zinc
μg	-	Microgram

ABSTRACT

Field experiment was carried out for two consecutive years at the research farm of Nagaland University, School of Agricultural Sciences and Rural Development, Medziphema Campus during 2016 and 2017. The experiment was carried out in a split-split plot design consisting of 18 (eighteen) treatments *i.e.*, Sulphur - 0, 20 and 40 kg ha^{-1} (S_0, S_1 & S_2 respectively), Boron - 0, 1 and 2 kg ha^{-1} (B_0, B_1 & B_2 respectively) and Phosphorus Solubilizing Biofertilizer (PSB) - 0 and 200 g per 10 kg seeds (P_0 & P_1 respectively) on soybean variety JS 97-52. The highest plant height (96.00 cm), number of leaves (36.08), number of branches (7.10), number of nodules (51.83) and plant dry matter (39.69 g) were recorded in plots receiving 20 kg S, 2 kg B and 200 g PSB per 10 kg seeds. The number of pods per plant and number of filled pods per plant were significantly influenced by Sulphur, Boron and Phosphorus Solubilizing Biofertilizer (PSB) interactions. The numbers of seeds per pod and seed index were found to be non-significant among the treatments. Synergistic interaction effect was observed between Sulphur and Boron on the yield attributing parameters of soybean during the two years research investigation. The yield of soybean was observed to increase with increasing dosage of fertilizer and the highest biological yield of 53.21 q ha^{-1}, seed yield of 21.76 q ha^{-1}and stover yield of 31.45 q ha^{-1} was recorded with application of Sulphur @ 40 kg ha^{-1}, Boron @ 2kg ha^{-1} and seed treatment with Phosphorus Solubilizing Biofertilizer @ 200g/10kg seeds. The nutrient concentration in the stover and seeds increases when the levels of Sulphur and Boron applications were increased. Seed treatment with Phosphorus Solubilizing Biofertilizer @ 200 g 10 kg^{-1} seeds was beneficial for increasing the nutrient content in stover and seeds of soybean. Application of Sulphur and Boron either alone or combined along with seed treatment with Phosphorus Solubilizing Biofertilizer improves the nutrient uptake of N, P, K, S and B by seeds and stover. The highest total nutrient uptake of 209.77 kg N ha^{-1} 18.58 kg P ha^{-1}, 101.79 kg K ha^{-1}, 16.46 kg S ha^{-1} and 137.70

g B ha^{-1} was obtained with combined application of Sulphur @ 40 kg ha^{-1}, Boron @ 2kg ha^{-1} along with seed treatment with Phosphorus Solubilizing Biofertilizer @ 200g/10kg seeds. Sulphur fertilization have significant influence on the protein content, protein yield as well as oil content and yield indicating the importance of sulphur in oil seeds production. Sulphur application was observed to have increased the S status of post harvest soil. Boron fertilization has increased the B content of the soil after harvest. Seed treatment with Phosphorus Solubilizing Biofertilizer must have solubilizes the insoluble inorganic phosphate present in the soil thereby increases the P content of post harvest soil. The available N in the post harvest soil was increased as a result of enhanced root nodulation and N_2 fixation through improved nutrient availability. The soil microbial biomass carbon of 236.11 μg g^{-1} and soil respiration 6.99 μg C g^{-1} soil hr^{-1} was highest with $S_2B_2P_1$ - while the lowest was observed in control ($S_0B_0P_0$) with 167.59 μg g^{-1} and 4.63 μg C g^{-1} soil hr^{-1} respectively. The nutrient use efficiency of sulphur and boron were higher at lower dose. Application of 20 kg S ha^{-1} and 1 kg B ha^{-1} give higher nutrient use efficiency which thereafter decline when 40 kg S ha^{-1} and 2 kg B ha^{-1} were applied indicating plants grown in deficient soil have higher sorption of S and B at lower dose. Soybean responds well to the increased application of Sulphur and Boron along with seed treatment with Phosphorus Solubilizing Biofertilizer (PSB). Application of Sulphur @ 40kg ha^{-1}, Boron @ 2kg ha^{-1} and Phosphorus Solubilizing Biofertilizer (PSB) @ 200g/10kg seeds was found to be optimum under foothill condition for soybean production.

CHAPTER I

INTRODUCTION

INTRODUCTION

Soybean (*Glycine max* L. Merril) is a leguminous crop belonging to the family Leguminosae. The centre of origin of soybean is reported to be China. Soybean is one of the important oil and protein containing crop of the world. The crop is cultivated in about 121.87 mha of land with an annual production of approximately 338.08 million metric tons and productivity of 2.77 metric tons ha^{-1} in the world (USDA, 2020). In India, soybean is cultivated in 11.39 million hectares of land with a total production of 10.56 million tonnes (ICAR, 2018). In India, Madhya Pradesh is the largest producer of soybean and is known as the "Soya state" (Chaithra and Hebsur, 2018).

Soybean forms symbiotic association with *Rhizobium japonicum* which has the capacity to fix 20% of the atmospheric nitrogen throughout the world annually (Franco, 1978). Soybean is a rich source of high quality protein (40-42%), oil (18-20%) and 24-26% carbohydrate and other nutrients like calcium, iron and glycine (Fatima *et al.* 2006). Soybean protein is rich in the valuable amino acid lysine (5%) which is deficient in most of the cereals (Kumar *et al.* 2017). In addition, it contains good amount of minerals, salts and vitamins (thiamine and riboflavin). The sprouting grains of soybean contain a significant amount of vitamin C, vitamins (thiamine and riboflavin), minerals, salts (Singh *et al.* 2003). Soybean helps in preventing heart diseases, cancer, HIV etc (Kumar, 2007). Soybean is the richest and cheapest source of best quality protein and fat and hence, it is called as vegetarian meat and wonder crop.

Soybean adapts well to a wide range of climatic conditions and soils. The optimum temperature range for soybean is 26^{o}C to 30^{o}C. Soybean is a thermo sensitive crop and usually grown in an environment with temperature ranges between 10^{o}C to 40^{o}C (Whighum, 1983). Soybean is a short day plant and sensitive to photoperiods. Sandy loam having good organic matter content is considered as the best soil type for soybean cultivation. Soils with a neutral range of pH having a fair degree of water retention capacity are however better suited for its cultivation. Soybean fits very well into India's climatic conditions and cropping patterns. The average annual rainfall of 75-125 cm found in most parts of the country was close to ideal for growing soybean without irrigation. It was found that soybeans yielded 4-8 times as much protein per unit area of land as common Indian pulses plus large quantities of vegetable oil. Encouraged by these extremely promising findings, in 1967, the All India co-ordinated research project on soybean was started as a team effort to develop the soybean as a new protein food source. Thus, the importance of soybean cultivation began in India.

The North Eastern Region of India is one of the major soybean producing belts of India where it is grown on slopes, jhum land, terraces and plains. It is a potential crop of the region and primarily grown as a pulse crop as well as intercrop with maize, ragi, arhar etc. In Nagaland the total area under soybean cultivation is 24.68 thousand ha with a total production of 31.17 thousand tonnes in the year 2015-2016 (Statistical Handbook of Nagaland, 2017). It is one of the most popular food items for majority of the Nagas and is utilized as a pulse crop as well as a fermented products locally called as 'Axone' (Sumi) or 'Dzacie' (Angami). In spite of its popularity in the state, very little priority is given by the farmers for large scale cultivation as a sole crop due to its low productivity. Soybean has the capacity to fix about 240-250 kg N ha^{-1} through symbiosis (Chandel *et al.* 1989). The nitrogen requirement of soybean is substantially fulfilled through symbiotic nitrogen fixation with *Rhizobium.*

In recent years, the use of secondary and micronutrients in crop production has been gaining importance due to its widespread deficiency in various parts of the country. Soybean as an oilseed crop requires more sulphur than many other crops for its proper growth and yield (Jamal *et al.*, 2010). Sulphur is an essential secondary plant nutrient which is required by plants and animals in approximately the same amount as phosphorus and few years back it was a neglected element. Sulphur is taken up by plants in sulphate (SO_4^{2-}) form. Sulphur deficiency has become widespread over the past several decades in most of the agricultural areas of the world, becoming a limiting factor to higher yields and fertilizer efficiency. Intensification of agriculture with high yielding crop varieties and multiple cropping, coupled with use of high analysis S-free fertilizers and restricted use of organic manures, has accelerated the depletion of soil reserves. Sulphur plays a very important role in plant; aids in stabilization of protein structure, involve in metabolic activities of vitamins, helps in synthesis of sulphur containing essential amino acids and coenzyme, chlorophyll formation, takes part in N-metabolism and promotes nodulation for N_2-fixation in legumes. The response of soybean to sulphur application has been reported by several workers (Brar *et al.,* 2010; Chaurasia *et al.,* 2009; Farhad *et al.*, 2010; Imade *et al.*, 2010).

As macronutrient requirements are met, it becomes possible that micronutrient requirements of soybean plant could be limiting optimum production, and although boron is termed a micronutrient, its role within the plant is widespread. Boron has long been recognized as an essential micronutrient for soybean. However its primary role and mode of action remain unknown. The role of B in plant is still the least well understood of all mineral nutrients (Mengel *et al* 2001). Boron play many important roles in plants such as synthesis of cell wall, sugar transport, cell division and differentiation, membrane functioning, root elongation, and regulation of hormone levels in plants (Marschner, 1995; Cakmak and Omheld, 1997). Boron deficiency in soybean hampers meristematic tissue development resulting in poor growth, biomass and yield (Shinde *et al.,* 2015). Boron is widely deficient in acidic soils of India (Barman *et al.,* 2014), coarse textured soils and soils low in organic matter (Ravi *et al.,* 2017) and is considered as one of the most commonly deficient micronutrients in agriculture. The response of soybean to boron application has been reported by several workers (Devi *et al.*, 2012; Ismail *et al*., 2013; Meshram *et al.,* 2017; Sarker *et al.,* 2002).

Biofertilizers are low cost and eco-friendly products containing live or latent cells of efficient strains of nitrogen fixing, phosphate solubilising or cellulolytic micro-organisms used for application to seed, soil or composting areas with the objective of accelerating microbial processes which augment the availability of nutrients that can be easily absorbed by plants. Biofertilizers has a huge potential for supplying plant nutrients which can reduce the dose of chemical fertilizers by 25-50% (Vance, 1997). Beneficial microorganisms in biofertilizers accelerate and improve plant growth and protect plants from pests and diseases. The use of phosphorus solubilizing biofertilizer solubilizes insoluble inorganic phosphate into soluble inorganic phosphate by producing organic acids, chelation and exchange reactions (Singh *et al.,* 2010), saving chemical fertilizers significantly and making it available to plants. In acidic soils of Northeastern Region of India, the use of phosphorus solubilizing biofertilizer has huge potential to overcome the deficiency of phosphorus due to its fixation induced by the high soil acidity which poses a limiting factor to crop production. The use of PSB as inoculants increases the P uptake by plants. Kumar *et al.* (2017) opined that phosphate solubilizing bacteria has the advantage of enhancing the productivity of soybean in areas where productivity is usually low due to imbalanced nutrient application and use of traditional varieties. The role and importance of biofertilizers in sustainable crop production has been reviewed by several authors (Dhage *et al.*, 2008; Devi *et al.*, 2013; Singh *et al.*, 2015; Verma *et al.*, 2018).

Thus, keeping in mind the widespread deficiency of phosphorus, sulphur and boron in acidic soils and considering the importance of sulphur and boron on the growth and yield of soybean and phosphorus solubilizing biofertilizer for quality production and in improving soil fertility, the research work entitled "Effect of sulphur, boron and phosphorus solubilizing biofertilizer on soybean (*Glycine max* L. Merril) under foothill condition of Nagaland" was undertaken with the following objectives:

- To study the effect of sulphur, boron and phosphorus solubilizing biofertilizer on growth, yield and quality attributes of soybean.
- To study the effect of sulphur, boron and phosphorus solubilizing biofertilizer on nutrient uptake by soybean.
- To study the effect of sulphur, boron and phosphorus solubilizing biofertilizer on soil chemical properties.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 Effect of Sulphur on Soybean

Ganeshamurthy (1996) studied the response of soybean to sulphur application and reported that the optimum response to sulphur was at 40 kg S ha^{-1}. Application of S also significantly increased the S uptake, oil content of grain and oil yield.

Ganeshamurthy and Reddy (2000) opined that increased number and size of root nodules resulted in higher N_2 fixation which ultimately contributes to higher N content in soybean.

Shrivastava *et al.* (2000) observed that application of adequate amount of sulphur into the soil resulted in enhanced absorption and translocation of sulphur by the plants which leads to increase S content in stover and seeds soybean.

Wani *et al*. (2000) opined that improved soil nutrient availability and increased root activity resulted in higher nutrient uptake by the crops through combined applicationt of N and S.

Majumdar *et al.* (2001) reported that P and S levels significantly increased the grain and straw yields, pods per plant, 100-seed weight, oil and protein content and their yields and N, P and S uptake by soybean. The N:S ratio in the seed reduced significantly by both P and S application. Application of 60 kg P_2O_5 along with 40 kg S ha^{-1} was the optimum rate of P and S to obtain the highest yield.

Singh *et al.* (2001) opined that sulphur application enhance the uptake of phosphorus and potassium by plants.

Sangale and Sonar (2004) found that application of increasing S levels up to 30 kg ha^{-1} increased the seed yields over the control. The highest soybean yield of 25.1 q ha^{-1} was observed at 30 kg S ha^{-1}. Treatments with 40 and 50 kg S ha^{-1} slightly reduced the yields

Jamal *et al*. (2005) observed that maximum response in terms of growth characteristics, yield components, seed and oil yield were obtained when 40 kg S ha^{-1} and 43.5 kg N ha^{-1} were applied together.

Pal and Phogat (2005) observed that the N, P K and S content and uptake by mustard crop were increase with application of sulphur.

Sharma and Singh (2005) opined that sulphur stimulates improved vegetative structure for nutrient absorption and create strong sink through production of assimilates and development of reproductive structure.

Biswas *et al.* (2006) revealed that application of sulphur and molybdenum had significant effect on nodulation and protein content of soybean. Application of different levels of S had significant effect on N, K, S, Ca, Mg, Zn and B content in soybean.

Chaurasia *et al.* (2009) reported that application of 40 kg S ha^{-1} resulted in significant increase in yield, nodulation, growth and physiological characters of soybean, but the significant response was observed upto 30 kg S ha^{-1}.

Brar *et al.* (2010) study the response of soybean to different levels of phosphorus (P) and sulphur (S) and found that phosphorus application resulted in additional grain yield to the tune of 1.8 and 4.2 q ha^{-1} from research farm and farmers' field respectively. Addition of S further improved grain yield of soybean. Phosphorus and sulphur uptake and apparent recovery efficiency increased significantly with P and S application. Response of soybean to P and S application was higher when sulphated phosphate was applied.

Imade *et al.* (2010) Application of 20 kg S ha^{-1} recorded significantly highest values of yield attributes, seed yield, oil content, protein content and nutrient uptake over 0 kg S ha^{-1}. Application of 75% P_2O_5 (56.25 kg ha^{-1}), 20 kg S ha^{-1} and Rhizobium+PSB seed inoculation recorded significantly highest seed yield but was on par with 100% P_2O_5 (75 kg ha^{-1}), 20 kg S ha^{-1} and Rhizobium+PSB seed inoculation indicated 25% saving of phosphorus requirement of soybean crop.

Farhad *et al.* (2010) observed that sulphur fertilizer had significant effect on yield and yield attributes of soybean. Application of sulphur @ 20 kg ha^{-1} produced the highest plant height, seed yield, 1000-seed weight and straw yield. Potassium in combination with Sulphur showed significant effect on yield and yield attributes of soybean. Combined application of Potassium @ 40 kg ha^{-1} and sulphur @ 20 kg ha^{-1} resulted in the highest seed yield, plant height, 1000-seed weight, straw yield, and protein and oil contents of soybean. On the other hand, in all the cases the lower response was found from the control treatment.

Najar *et al.* (2011) uncovered that maximum growth, nodulation, yield and quality of soybean was recorded with 40 kg S ha^{-1} which was at par with 30 kg S ha^{-1}. Stover and grain yield of soybean increased in the tune of 66.0 and 53.4% over control due to addition of 40 kg S ha^{-1} respectively. Application of 40 kg S ha^{-1} recorded the highest total N, P, K, S, Ca and Mg nutrients uptake by soybean.

Shivran *et al.* (2012) while assessing the response of soybean (cultivar JS-335) to phosphorus and sulphur nutrition with phosphorus solubilizing bacterial inoculation on yield and quality of grain revealed that yield attributes, seed and straw yield were increased with the application of sulphur and phosphorus with phosphorus solublizing bacterial inoculation. They concluded that soybean production may be enhanced by the application of sulphur at 40 kg ha^{-1} and phosphorus at 40 kg P_2O_5 ha^{-1} with phosphorus solubilizing bacterial inoculation.

Chauhan *et al.* (2013) reported that in a field experiment during 2009-10 and 2010-11, combined application of K 20 kg ha^{-1}, S 20 kg ha^{-1} and Zn 5 kg ha^{-1} recorded 91% increased in number of nodules over control, seed yield increased by 43.2% and 32.7%, oil percentage increased by 1.3% and 1.1% in both years respectively.

Mahmoodi *et al.* (2013) observed that sulphur enhanced the branches per plant, capsules per plant, grains per capsule and 100 grain weight of soybean.

Choudhary *et al.* (2014) studied the response of soybean to S and Zn application and found that the yield, yield attributing traits and quality parameters are significantly affected by sulphur and zinc doses. It was reported that highest grain yield (15.30 g pot^{-1}) and the yield attributes *viz;* plant height (43.5 cm), branches per $plant^{-1}$ (6.7), capsule $plant^{-1}$ (13.0), grains $capsule^{-1}$ (3.2), 100 grain weight (9.67 g) were obtained from treatment combination of 40 ppm S and 5 ppm Zn. Highest protein (38.64%) and oil (21.54%) was observed with application of 60 ppm S.

Reddy *et al.* (2014) observed that soybean significantly responded to sulphur @ 40 kg ha^{-1} (Bensulf) along with RDF. The percent yield increase varied between 12 to 16% and BC ratio ranged from 2.15 to 4.05.

Sharma *et al.* (2014) revealed that seed yield, nutrient uptake and protein content in soybean seeds were significantly increased with application of S (gypsum @ 20 kg ha^{-1}) alongwith recommended dose of N.

Lakshman *et al.* (2015) revealed that higher branches per plant, number of nodules were recorded with higher levels of sulphur application. Maximum seed yield (1.9 t ha^{-1}) was observed with split application of 45 kg sulphur as 50% basal and 50% at flowering. Stover yield was highest with basal application of 45 kg sulphur. The quality parameters like protein content and oil content in seed was highest with split application of 45 kg sulphur as 50% basal and 50% at flowering.

Parakhia *et al.* (2016) observed that in a pot experiment, significantly higher number of nodules per plant (4.63), pods per plant (23.52) and seed yield (6.78 g $plant^{-1}$) were observed with application of sulphur @ 15 mg kg^{-1}.

Sahebagouda *et al.* (2019) revealed that application of 100% RDF + poultry manure at 6 t ha^{-1} + sulphur at 40 kg ha^{-1} through gypsum recorded significantly higher growth and yield parameters like plant height (73.67 cm), number of leaves per plant (16.22), number of branches (10.30), dry matter content (32.33g $plant^{-1}$), test weight (13.88 gm) and yield parameters like number of pods $plant^{-1}$ (123.33), pod yield $plant^{-1}$ (63.17g), pod yield (30.30q ha^{-1}), seed yield (26.90 q ha^{-1}) and haulm yield (44.15 q ha^{-1}).

Sree (2020) opined that application of 30 and 40 kg S ha^{-1} along with recommended dose of fertilizers gives the highest yields and protein content in pulses.

2.2 Effect of boron on soybean

Rahman *et al.* (1999) observed that application of 0.4 mg B $litre^{-1}$ was most beneficial for all the growth characters including nodule formation at the early stage (20 DAS) of development of soybean plants.

Malewar *et al.* (2001) observed significant increase in oil content due to the positive influence of boron on biosynthesis of oil and fatty acids.

Yang *et al.* (2004) observed that high B was found to ameliorate Al toxicity by significantly increasing the growth characters including root length, and epicotyl length and fresh weight. However, high B concentration did not significantly increase chlorophyll content under Al stress.

Ross *et al.* (2006) reported that boron fertilization increased seed yields from 4 to 130%. Application of 0.28 to 1.12 kg B ha^{-1} during early vegetative or reproductive growth was sufficient to produce near maximal yields.

Byju *et al.* (2007) in an experiment to study the fertilizer B requirement in sweet potato observed that the highest BUE was obtained with application of B at the rate of 1.0 kg ha^{-1}.

Rajendran *et al.* (2012) reported that significantly higher growth and yield attributes were obtained with application of boron @ 1 kg B ha^{-1} in soybean.

Sun *et al.* (2013) reported that Mo, B, and combined Mo and B treatments in soybean increased the soil microbial populations, stimulated the rhizosphere metabolisms, and improved the soil enzyme activities. The Mo and B combination treatments were more beneficial for the soybean rhizosphere soil than that of Mo-only or the B-only treatments, which suggests that the two elements have complementary functions in the biological processes of the soybean rhizosphere.

Shinde *et al.* (2015) observed that application of boron @ 2 kg ha^{-1} recorded a seed yield (2526 kg ha^{-1}) and oil yield (513 kg ha^{-1}) which was at par with application of zinc @ 10 kg ha^{-1} which recorded 2290 kg ha^{-1} and 556 kg ha^{-1} respectively.

Kundu *et al.* (2016) observed that application of 2.0 and 4.0 kg ha^{-1} boron recorded the highest uptake of S and B by sunflower and mustards.

Rathod *et al.* (2016) unveiled that B uptake by soybean increased with application of boron through borax through soil and foliar spray. The application of zinc, boron, along with decreasing doses of lime individually or in combination gradually increased the uptake of B by grain and straw of soybean.

Yadav *et al.* (2016) observed significant increase in yield attributes of mustard with soil application of 1.5 kg B ha^{-1}. Highest stover and seed yield was obtained with application of RDF + 1.5 kg B ha^{-1}. The protein and oil content were also significantly increased with boron fertilization.

Chatterjee and Bandyopadhyay (2017) recorded that flowering and pod setting are positively influence by B which resulted in higher number of pod and total pod yield per plant in cowpea.

Ravi *et al.* (2017) opined that boron have favourable influence on root nodulation and seed formation process which increases the yield in soybean. Growth parameters like plant height and number of branches per plant showed significant variation with different levels of boron along with recommended dose of fertilizer application.

Chaithra and Hebsur (2018) revealed that recommended package of practices (RPP) along with soil (@ 2.5 kg ha^{-1}) + foliar (@ 0.5%) application of solubor improved the growth and yield parameters significantly. The highest number of effective nodules per plant (18.64) was recorded with soil application of solubor @ 5 kg ha^{-1}.

Uddin *et al.* (2020) found that highest number of pods plant^{-1} (5.02), number of effective pods plant^{-1} (4.03), number of seeds pod^{-1} (4.04), 1000-seed weight (412.74 g), seed yield (1.54 t ha^{-1}), stover yield (3.05 t ha-^{1}), biological yield (4.59 t ha^{-1}), and harvest index (36.98 %) were observed in French bean with application of boron level at 1.5 kg ha^{-1}.

Effect of phosphorus solubilizing biofertilizer on soybean

Gyaneshwar *et al*. (1998) reported that improved P solubilization through phosphate solubilizing micro-organisms promotes biological N_2 fixation and production of plant growth regulators.

Srivastava *et al*., 1998 opined that the improved nutrient uptake and growth through increased root nodulation and nitrogenase enzyme activity increased number of pod per plant.

Son *et al.* (2006) reported that application of Bradyrhizobia (*Bradyrhizobium japonicum*) and phosphate solubilizing bacteria (*Pseudomonas* spp.) can enhance the number of nodules, dry weight of nodules, yield components, grain yield, soil nutrient availability and uptake of soybean crop.

Dhage *et al.* (2008) revealed that 100 % RDF with dual inoculation (*Rhizobium* + PSB) resulted in the highest grain (1363 kg ha^{-1}) and straw yield (1798 kg ha^{-1}). Biofertilizers increased nodule number, fresh as well as dry weight of nodule per plant. The yield and nutrient (N, P and K) uptake also increased due to dual inoculation in presence as well as absence of chemical fertilizers.

Dhage and Kachhave (2008) observed that dual inoculation of *Rhizobium* and PSB with 100% RDF recorded the highest N (6.23%), P (2.68%) and K (2.29%) contents in seed and highest grain yield (15.46 t ha^{-1}). Dual inoculation of

Rhizobium and PSB also improved the quality of soybean in presence as well as absence of chemical fertilizer. The residual soil fertility was improved with 100% RDF + *Rhizobium* + PSB.

Sandeep *et al.* (2008) in a pot experiment conducted using Phosphate Solubilizing Microorganisms (PSM) isolated from the rhizosphere soil to investigate their effect on releasing unavailable 'P' and improving growth parameters, with a particular focus on soybean crop revealed that yield and nutrient uptake, nodulation efficiency and the available 'P' content in soil were significantly enhanced showing the positive effect of microbial inoculation.

Argaw (2012) observed that dual inoculation with *Bradyrhizobium japonicum* and PSB significantly increased plant height at harvest, number of nodules per plant, nodule volume per plant, nodule fresh weight per plant, and shoot height at late flowering and early pod setting in soybean. Similarly, co-inoculation with *Bradyrhizobium japonicum* (TAL-378) and PSB, and dual fertilization of nitrogen (N) and phosphorus (P) fertilizers significantly increased number of pods per plant, number of seeds per pod per plant and seed yield ha^{-1} compared to the other treatments. Analysis of plant tissue also indicated that dual inoculation of *Bradyrhizobium japonicum* (TAL-379) and PSB yielded the highest total N whereas the lowest was recorded for the negative control. Likewise, dual inoculation with *Bradyrhizobium japonicum* (TAL-378) and PSB and the positive control gave the highest plant P compared to all other treatments.

Devi *et al.* (2012) reported that significantly higher number of nodules per plant, dry weight of nodules per plant, number of pods per plant and 100 seed weight were produced with application of SSP + PSB. Maximum grain yield and total phosphorus uptake were also recorded with SSP + PSB.

Devi *et al.* (2013) revealed that integration of 75% RDF with vermicompost at the rate 1 t ha^{-1} and PSB produced significantly higher plant height, number of nodules plant, dry weight of nodules $plant^{-1}$, pods $plant^{-1}$ and seed index than the other treatments. Similarly, significantly higher grain and stover yield were obtained from the application of 75% RDF as inorganic fertilizer in combination with vermicompost at the rate of 1 t ha^{-1} followed by seed inoculation of PSB. The oil and protein content of seed were increased significantly due to the application of 75% RDF coupled with vermicompost at the rate of 1 t ha^{-1} and PSB. The available N, P and K of soil after the harvest of soybean were improved significantly due to the integration of inorganic fertilizers with organic manures.

Khaswa *et al.* (2014) found that application of 40 kg P_2O_5 ha^{-1}, SSP and naphthalene acetic acid (NAA) recorded significantly higher pooled plant height (51.65, 50.82 and 51.17 cm), branches $plant^{-1}$ (4.56, 4.43 and 4.48), oil content (21.40, 20.91 and 21.20%), oil yield (558.89, 528.75 and 521.79 kg ha^{-1}), seed protein yield (1111.56, 1039.96 and 1045.60 kg ha^{-1}), grain yield (25.95, 25.12 and 24.23 q ha^{-1}) and stover yield (37.37, 36.23 and 35.73 q ha^{-1}) over other treatments.

Rana *et al.* (2014) observed that the growth attributes of soybean increased with the application of 60 kg P_2O_5 ha^{-1} along with *Rhizobium* and phosphorus solubilizing bacteria but found to be at par with the treatment getting 45 kg P_2O_5 ha^{-1} along with *Rhizobium* and phosphorus solubilizing bacteria. They concluded that net benefits can be obtained with the treatment receiving the application of 45 kg P_2O_5+*Rhizobium*+PSB over the recommended dose of phosphorus which results in net saving of 15 kg P_2O_5 ha^{-1}.

Pindkurwar *et al.* (2015) observed significantly higher seed and straw yield of soybean with the application of liquid based *Rhizobium* + PSB with 100% RDF.

Diep *et al.* (2016) revealed that application of rhizobial inoculants and/or PSB inoculant produced significantly higher yield component, grain yield than control. Use of biofertilizer for soybean cultivation supported higher yield component, grain yield, protein and oil in seed than control and equivalent with treatment of 100 kg ha^{-1} thermophosphate (15% P_2O_5) + 25 kg ha^{-1} NPK 16:16:18.

Raja and Takankhar (2017) revealed that dual inoculation *Bradyrhizobium* and PSB significantly improves the growth parameters *viz.* plant height, number of functional leaves, root length and dry matter yield of soybean.

Sentimenla (2020) found that the application of 10 tons of FYM ha^{-1} along with biofertilizer rhizobium and PSB either through seed or soil treatment obtained higher seed yield, net return and B:C ratio over traditional farmers' practice.

Naaz and Hasan (2020) reported that plant height (cm) and number of branches per plant in soybean were significantly increased in co-inoculation of Rhizobium + PSB.

Effect of Sulphur, Boron and Phosphorus Solubilizing Biofertilizer interaction on soybean

Majumdar *et al.* (2001) opined that application of 60 kg P_2O_5 along with 40 kg S ha^{-1} was the optimum dose of P and S for obtaining the highest yield in soybean. The grain and straw yield, pods per plant, 100 seed weight, oil and protein content and their yields, N, P and S uptake by soybean increased significantly at all levels of phosphorus and sulphur application.

Sarker *et al.* (2002) revealed that yield and yield attributes of soybean significant when S and B were applied individually but their interaction were not significant. The highest biological yield and most of the yield attributes were obtained from the treatment combination of 30 kg S and 1.0 kg B ha^{-1}.The uptake of S and B by grain was significant by S and B application individually. The protein and oil content were increased with increasing level of S and B.

Lalitlanmawia *et al*. (2005) revealed that application of P and S significantly increases the number of nodules per plant in soybean.

Saxena and Nainwal (2010) evaluate the response of sulphur and boron nutrition on yield and yield attributes, harvest index (HI) and economics of soybean (variety PS 1042) in kharif seasons of 2007 and 2008 revealed that the effect of different doses of sulphur and boron application on seed yield of soybean was significant and its interaction was also significant indicating that there is differential requirement of sulphur and boron to maximize yield. On mean performance basis, the application of 30 kg S ha^{-1} gave maximum yield.

Devi *et al.* (2012) uncovered that yield attributing characters like number of branches per plant, pods per plant and 100 seed weight and yield were increased with application of sulphur and boron as compared to control. Application of 30 kg S ha^{-1} and 1.5 kg B ha^{-1} was found to be the optimum level for obtaining maximum yield attributes, yield, oil and protein content, total uptake of S and B, net return, cost and benefit ratio of soybean under upland condition.

Sentimenla *et al.* (2012) revealed that application of different levels of P and B significantly increased the plant height, number of nodules and maximum number of pods per plant in comparison to control. Highest seed yield (2.88 t ha^{-1}) and stover yield (3.74 t ha^{-1}) and protein content was recorded with application of 60 kg P_2O_5 ha^{-1} and 1.5 kg B ha^{-1}. The uptake of N, P, K and B was significantly increased with application of P and B either alone or in combination.

Akter *et al.* (2013) revealed that combined application of phosphorus @ 30 kg P ha^{-1} and sulphur @ 20 kg S ha^{-1} gave the highest number of pods $plant^{-1}$ (30.07), number of seeds $plant^{-1}$ (84.94), thousand seed weight (94.61 g) and the highest grain yield (2.29 t ha^{-1}).

Ismail *et al.* (2013) reported 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 kg S ha^{-1} and that of boron to the tune of 20 kg borax ha^{-1} application levels indicating their sufficient need for a crop like soybean.

Yadav *et al.* (2013) revealed significant interaction effect of phosphorus and sulphur on seed yield and stover yield. Significantly highest seed yield (3104 kg ha^{-1}) and stover yield (3408 kg ha^{-1}) was observed with combined application of 75 kg P_2O_5 ha^{-1} + 30 kg S ha^{-1}.

Dhage *et al.* (2014) unveiled that grain and straw yield, uptake of P and S, protein and test weight increased with increase in the rate of P and S application individually as well as in various combinations.

Ram *et al.* (2014) reported that the highest grain yield, protein, oil content, gross and net returns of soybean were recorded with 40 kg S ha^{-1}, which were statistically at par with 30 kg S ha^{-1} but significantly higher than other levels of sulphur. The boron level of 1.5 kg ha^{-1} recorded the highest grain yield, gross and net returns, being statistically at par with 1.0 kg B ha^{-1} but significantly higher than 0.5 kg B ha^{-1}. The highest S and B uptake were recorded in 40 kg S and 1.5 kg B ha^{-1} respectively. The highest grain yield recorded in 40 kg S ha^{-1} and 1.5 kg B ha^{-1} was statistically at par with 40 kg S ha^{-1} and 1.0 kg B ha^{-1}, 30 kg S ha^{-1} and

1.0 kg B ha^{-1}, 20 kg S ha^{-1} and 1.5 kg B ha^{-1} and 30 kg S ha^{-1} and 1.5 kg B ha^{-1} treatments but was significantly higher than all the other combinations of sulphur and boron.

Ganie *et al.* (2014) observed that the interaction between sulphur and boron have synergistic effect and significantly increased the N, P, K, S and B content and uptake of french bean in inceptisols of North Kashmir.

Layek *et al.* (2014) reported that application of S upto 30 kg recorded significantly higher growth parameters viz. plant height (57.62 cm), dry matter accumulation (36.66 g $plant^{-1}$), number of branches (3.10), leaf area index (2.89) etc. and yield attributes viz. number of pods $plant^{-1}$ (72.00), seed pod^{-1} (2.49), seed index (9.99 g) etc. and yield of soybean (1.73 t ha^{-1}) as compared to lower levels of S. Similarly application of B @ 1.0 kg recorded significantly higher growth parameters viz. plant height (57.23 cm), dry matter accumulation (36.37 g $plant^{-1}$), number of branches $plant^{-1}$ (3.11), leaf area index (2.70) etc. and yield attributes viz. number of pods $plant^{-1}$ (70.47), seed pod^{-1} (2.52), seed index (9.79) etc. and yield of soybean (1.75 t ha^{-1}). 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 (1.88 t ha^{-1}).

Kundu *et al.* (2016) observed that application of both sulphur and boron significantly and synergistically improved the oil and protein contents of sunflower and mustards.

Longkumer *et al.* (2017) opined that application of S and B, either alone or in combination, significantly increased the growth, yield and quality of soybean. Application of sulphur 40 kg S ha^{-1} resulted in best yield (1767 kg ha^{-1}) which was 21.2% higher than the yield at control (1458 kg ha^{-1}), while B produced maximum yield (1578 kg ha^{-1}) at 1.5 kg B ha^{-1}. Combined application of 40 kg S ha^{-1} and 1.5 kg B ha^{-1} resulted in 57.4% yield improvement, 28% increase in protein and 33% increase in oil content over control, which shows their synergetic effect on crop performance. Similarly, the nutrient uptake of N, P, K, S and B was highest with application of 40 kg S ha^{-1} and 1.5 kg B ha^{-1}.

Meshram *et al.* (2017) recorded that, quality characters, nutrient content and uptake viz., oil content and oil yield kg ha^{-1}, sulphur and boron content in grain and straw and its uptake, available sulphur and boron in soil were significantly more with application of 40 kg S ha^{-1}. In case of boron application, quality characters, nutrient content and uptake by seed and straw were significantly increased with the application of 1.5 kg B ha^{-1}.

Ravi *et al.* (2017) observed that application of RDF + 12 kg $ZnSO_4$ ha^{-1} + 30 kg S ha^{-1} + 1.0 kg B ha^{-1} recorded significantly higher seed yield (22.7 q ha^{-1}) which was at par with RDF + 12 kg $ZnSO_4$ ha^{-1} + 30 kg S ha^{-1} + 1.5 kg B ha^{-1} (21.5 q ha^{-1}) compared to other treatments. Further, significantly higher uptake of N (163.0 kg ha^{-1}), P (18.5 kg ha^{-1}), K (74.61 kg ha^{-1}), S (22.16 kg ha^{-1}) and B (0.14 kg ha^{-1}) were recorded with application of RDF + 12 kg $ZnSO_4$ ha^{-1} + 30 kg S ha^{-1} + 1.0 kg B ha^{-1} which was on par with RDF + 12 kg $ZnSO_4$ ha^{-1} + 30 kg S ha^{-1} + 1.5 kg B ha^{-1} (160.5, 16.48, 73.19, 20.12 and 0.12 kg ha^{-1}) respectively.

Kamboj and Malik (2018) showed that application of phosphorus and boron had synergistic effect on yield, P and B in content seed and straw of green gram. Highest seed and straw yield, P and B in content seed and straw of green gram was found when 100 mg P kg^{-1} and 1.0 mg B kg^{-1} in soil. Application of P and B also improves protein content however, their interaction was non-significant. The uptake of P and B increases with their successive P and B application level.

Modhavadiya *et al.* (2018) revealed that yield was significantly influenced by the various levels of sulphur and boron. The application of sulphur 30 kg S ha^{-1} and boron 3 kg B ha^{-1} significantly increased the no. of capsule $plant^{-1}$, dry matter yield (15.33 gram $plant^{-1}$) and seed yield (5.66 g $plant^{-1}$).

Nagar *et al*. (2018) observed that application of sulphur up to 60 kg S ha^{-1} along with *Rhizobium* and PSB recorded significantly higher number of branches per plant in soybean.

Patel and Zinzala (2018) showed that application of sulphur upto 45 kg ha^{-1} increases the nutrient concentration and uptake of N, P, K, S and B in pods and haulm by summer groundnut. Similar trend on nutrient concentration and uptake of N, P, K, S and B in pods and haulm was observed with boron application. Application of sulphur and boron increased the primary nutrient availability in addition to sulphur and boron causing their absorption by summer groundnut.

Suman *et al.* (2018) noticed that increasing application of sulphur and phosphorus, singly as well as in combination, significantly increased the grain yield, protein and oil content, contents of N P, K and S over control. The interaction of S and P exhibited a strong synergistic relationship in soybean nutrition grown in deficient soil.

Timotiwu *et al*. (2018) confirmed that the growth response of soybean to increased phosphorus application was independent of boron fertilization.

Kalaiyarasan *et al.* (2020) found that application of 60 kg S ha^{-1} with B @ 1 kg ha^{-1} was significantly recorded maximum growth, yield attributes and yield, quality, nutrient uptake, post harvest soil nutrient status and sulphur use efficiency of hybrid sunflower.

Awal *et al.* (2020) opined that mustard crop fertilized with 40 kg S ha^{-1} in combination with 1 B kg ha^{-1} produced taller plant, higher number of branches and leaves in each plant and higher amount of dry matter per plant and the highest seed yield (2.73 t ha^{-1}).

Satya and Swami (2021) reported that significantly higher nitrogen and potassium uptake by seed and straw in black gram was observed with application of P @ 75 kg ha^{-1} and B @ 1.5 kg ha^{-1}.

Effect of Sulphur, Boron and Phosphorus Solubilizing Biofertilizer on soil fertility

Kothari and Jethra (2002) found that increasing the levels of S application increases the available N, P and S in soil.

Dhage *et al*. (2008) revealed that 100 % RDF with dual inoculation (*Rhizobium* + PSB) improved soil fertility by increasing organic carbon content and effective bacterial population in soil.

Najar *et al.* (2011) observed that the available S at harvest soil increased significantly with S level.

Sarawgi *et al.* (2012) revealed that seed treatment with biofertilizers had significant effect on microbial population in conjunction with P application in soybean field.

Kader and Mona (2013) recorded that application of sulphur and foliar spray with micronutrients (Zn and B) had significant effect on available N, P and K in soil. Combined application of (S + Zn + B) obtained the highest available N, P and K in soil. The highest available Zn and B were obtained with application of sulphur (S).

Meena and Ghasolia (2013) reported maximum microbial population in soil when soybean seeds were inoculated with phosphate solubilizers.

Dhage *et al.* (2014) observed that available P in soil increased with increasing levels of phosphorus. Similarly available S in the soil increased with increasing levels of sulphur.

Singh *et al.* (2014) observed substantial increased available N, P, K and S of soil with application of 20 kg S ha^{-1}.

Singh *et al.* (2015) observed that microbial inoculation increased the microbial biomass carbon over uninoculated control treatment due to increase in microbial cells in soil. AM fungi inoculation recorded significant increase in microbial biomass carbon over *B. japonicum* and PSB alone inoculations due to development of more fungal mycelium in soil.

Yadav *et al.* (2016) observed increase in boron availability in soil as a result of boron application.

Kumar *et al*. (2017) observed that the available N (216 kg ha^{-1}), K_2O (639.3 kg ha^{-1}) and S (12 mg kg^{-1}) were significantly increased with application of microbial inoculants. They also revealed that no significant differences were observed in soil pH, EC and $CaCO_3$ after harvest in soybean.

Chatterjee and Bandyopadhyay (2017) observed that application of molybdenum and biofertilizers as seed treatment along with foliar spray of boron had a significant influence on the availability of macro nutrients in the soil. Application of boron through foliar spray at four weeks of planting recorded significantly higher available N, P and K in soil.

Meshram *et al.* (2017) opined that application of different levels of sulphur significantly influenced the available sulphur in soil. Application of 40 kg S ha^{-1} recorded the highest available sulphur (23.18 mg kg^{-1}) in soil. The residual available sulphur and boron in soil increased with each increasing levels of boron. Application of 1.5 kg B ha^{-1} recorded the highest available boron in soil.

Suman *et al.* (2018) observed that increasing the levels of phosphorus and sulphur increases the available P and S in soil under soybean cultivation.

Verma *et al.* (2018) uncovered that in an integrated nutrient management practices, the microbial biomass carbon and enzymatic activity of soil was found to decreased gradually from flowering to harvesting stage as well as the depth 0-15 cm and 15-30 cm. The application of 75% NPK + 25% N through vermicompost + Rhizobium + PSB recorded the maximum microbial biomass carbon and enzymatic activity of soil at flowering and harvesting stage as well as both the depth 0-15 cm and 15-30 cm.

Game *et al.* (2020) found that maximum residual available nitrogen (198.2 kg ha^{-1}) and phosphorus (22.4 kg ha^{-1}) in soil was observed with the combined application of Azotobacter, PSB and Potash mobilizing bacteria (KMB) + 100% RDF. Further, the microbial activity was observed to remain at elevated level in the treatment where inoculation of Azotobacter, PSB and Potash mobilizing bacteria was given without addition of chemical fertilizers.

CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 Experimental Site:

The research investigation entitled **"Effect of sulphur, boron and phosphorus solubilizing biofertilizer on soybean (*Glycine max* L. *Merril*) under foothill condition of Nagaland"** was carried out in the experimental research farm of School of Agricultural Sciences and Rural Development (SASRD), Medziphema campus, Nagaland University. The experimental site is situated at 20˚45'43" N latitude and 93˚53'04" E longitude at an altitude of 310 m above mean sea level.

3.2 Climatic condition:

The experimental site lies in the humid sub-tropical zone with an average annual rainfall ranging from 2000 to 2500 mm. The mean summer temperature ranges from 21 to 32˚ C and rarely goes below 8˚C in the winter season.

3.3 Soil condition:

The soil of the experimental plot was characterized by well drained and sandy loam texture. The texture and fertility status of the soil was ascertained by collecting soil samples from a depth of 0-15 cm at random using quadrant methods by means of auger before and after harvest of the crop.

The collected samples were air dried and ground to pass through a 2 mm sieve and analyzed for physical, chemical and biological parameters following standard analytical procedures. The results thus obtained are presented in table 3.1.

Table: 3.1. Initial soil status of the experimental plot

SOIL PARAMETERS	METHODS	VALUE
Soil pH	Glass electrode pH meter (Richards, 1954)	5.49
Electrical Conductivity (EC)	Conductivity bridge (Richards, 1954)	0.20 dS m^{-1}
Organic Carbon (OC)	Rapid titration method outlined by Walkley and Black (1934) and expressed in percentage as described by Jackson (1973).	0.82 %
Cation Exchange Capacity (CEC)	1 *N* NH_4OAc at pH 7.0 (Chapman, 1965)	12.50 cmol (p^+) kg^{-1}
Available N	Alkaline potassium permanganate method as described by Subbiah and Asija (1956)	335.55 kg ha^{-1}
Available P	Brays and Kurtz method (1945)	8.45 kg ha^{-1}
Available K	Flame photometric method using neutral normal ammonium acetate (pH 7.0) (Jackson, 1973)	174.28 kg ha^{-1}
Available S	Turbidimetric method (Chesnin and Yien,1950)	7.35 mg kg^{-1}
Exchangeable Ca	1 *N* ammonium acetate extracts of soil by titration against EDTA (Black, 1965)	4.98 cmol (p^+) kg^{-1}
Exchangeable Mg	1 *N* ammonium acetate extracts of soil by titration against EDTA (Black, 1965)	0.42 cmol (p^+) kg^{-1}
Available Boron	Curcumin method (Dible *et al.*, 1954)	0.45 mg kg^{-1}
Soil Respiration (µg g^{-1} soil hr^{-1})	Alkali entrapment method (Macfayden, 1970)	4.58 µg C g^{-1} soil hr^{-1}
Soil Microbial Biomass Carbon (µg g^{-1} soil)	Fumigation-extraction method (Vance *et al*., 1987)	168.54 µg g^{-1}
Soil Texture	International pipette method using 1 *N* NaOH (Piper, 1966)	Sandy clay loam

3.4 Details of the experiment

3.4.1 Design and plan of layout

The field experiment was laid out in Split Split Plot Design (SSPD) with eighteen (18) treatments which were replicated thrice. The experiment was conducted for two consecutive years (2016 and 2017) on the same site. The whole experimental field was equally divided into three blocks and each block was again divided into equal sized plots measuring 2.25 m x 1 m to accommodate the treatments. Altogether there were 54 plots. The treatments were allotted randomly within the plots of each experimental block.

The details of the experiment conducted consist of the following components:

a) Crop : Soybean (*Glycine max* L. Merril)
b) Variety : JS 97-52
c) Experimental design : Split-split plot design
d) Plot size : 2.25 m x 1 m
e) Spacing : 45 cm x 10 cm (Row to Row X Plant to Plant)
f) Number of treatments : 18
g) Number of replications : 3
h) Total number of plots : 54

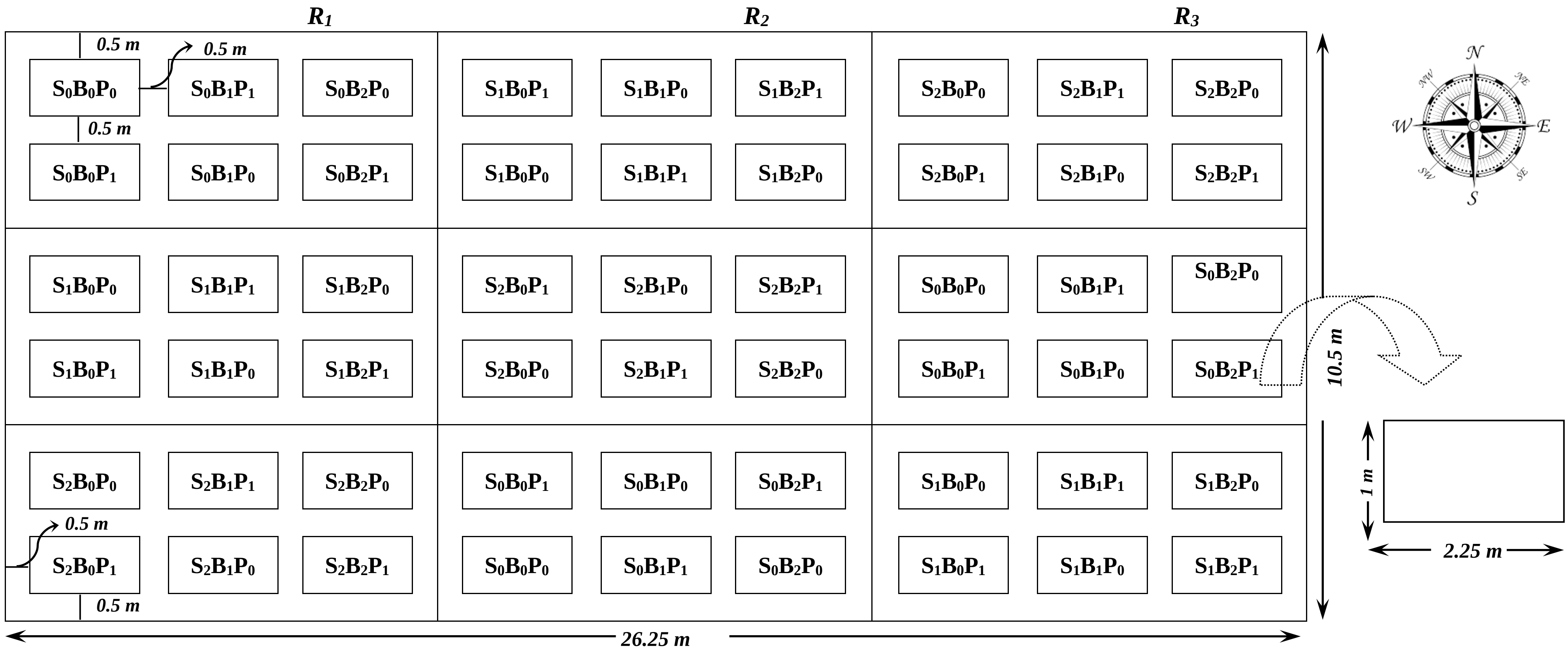
The details of the experiment are given below and the field layout is presented in Fig. 1.

3.4.2 Treatments details:

The recommended dose of fertilizers (RDF) NPK was applied in all the plots irrespective of the treatment.

Main plot factor	= Sulphur	: 0, 20, 40 kg ha^{-1} (S_0, S_1, and S_2 respectively)
Sub plot factor	= Boron	: 0, 1, 2, kg ha^{-1} (B_0, B_1, and B_2 respectively)
Sub-sub plot factor	= Phosphorus solubilizing biofertilizer (PSB)	: 0, 200 g per 10 kg seeds (P_0 and P_1 respectively)

Symbol used	Treatments
T_1	$S_0B_0P_0$ (control)
T_2	$S_0B_0P_1$
T_3	$S_0B_1P_0$
T_4	$S_0B_1P_1$
T_5	$S_0B_2P_0$
T_6	$S_0B_2P_1$
T_7	$S_1B_0P_0$
T_8	$S_1B_0P_1$
T_9	$S_1B_1P_0$
T_{10}	$S_1B_1P_1$
T_{11}	$S_1B_2P_0$
T_{12}	$S_1B_2P_1$
T_{13}	S_2 B_0P_0
T_{14}	$S_2B_0P_1$
T_{15}	$S_2B_1P_0$
T_{16}	$S_2B_1P_1$
T_{17}	$S_2B_2P_0$
T_{18}	$S_2B_2P_1$



Sulphur level (Main plot factor)

S_0= 0 kg/ha
S_1= 20 kg/ha
S_2= 40 kg/ha

Boron level (Sub plot factor)

B_0= 0 kg/ha
B_1= 1 kg/ha
B_2= 2 kg/ha

Phosphorus Solubilizing Biofertilizer level (Sub-sub plot factor)

P_0= 0 (Zero)
P_1= 200 g/10 kg seeds

Fig 1: Field layout of the experiment in split-split plot design

3.5 Cultivation details

3.5.1 Selection and preparation of field

A rectangular plot having uniform fertility and even topography was selected for conducting field trial. The experimental plot was ploughed in the first week of May 2016. The field was then harrowed and leveled properly. All the stubbles were removed and then the field was laid out according to the layout planned.

3.5.2 Fertilizer application

The recommended dose of fertilizer (RDF) of NPK i.e., 20 kg N, 80 kg P_2O_5, 40 kg K_2O was applied in all the plots irrespective of the treatments. The fertilizer S and B were applied to each plot as per the treatments.

3.5.3 Seed rate and sowing

The seeds were sown in each plot during last week of June by maintaining 10 cm plant to plant and 45 cm row to row spacing.

Seed treatment with phosphorus solubilizing biofertilizer (PSB) at the rate of 200 g per 10 kg seeds as per the treatments was done prior to sowing.

3.5.4 After care

Thinning and gap filling was done to maintain a uniform plant population. The first hand weeding was carried out at 20 DAS and later at 15 days interval.

3.5.5 Harvesting and threshing

The crops were harvested in the month of November at regular interval depending on the maturity level of the pods. The crop was harvested from ground level and plot wise harvested crop were sun dried, threshed and then cleaned manually.

3.6 Observations to be recorded:

3.6.1 Growth parameters

3.6.1.1 Plant height (cm)

Five plants from each plot were randomly selected and tagged for recording the plant height at different growth intervals. The plant height was measured in centimeter (cm) from the ground level to the top of the plants at 30, 60 and 90 days after sowing (DAS). The average height of the plant for each treatment was calculated.

3.6.1.2 Number of leaves per plant

The number of leaves per plant was recorded from the tagged plants from each plot at 30 DAS, 60 DAS and 90 DAS. The average number of leaves per plant for each treatment was calculated and recorded.

3.6.1.3 Nodule count

The nodule count was recorded at 45 DAS and 60 DAS by carefully uprooting five sample plants from each plot with the help of khurpi and then washed the roots and nodules with gentle stream of water. The nodules were then detached from the roots and counted, and the average number of nodules per plant for each treatment was then recorded.

3.6.1.4 Dry weight of plants (at 60 DAS and harvest)

The samples for dry weight of plants was obtained from all the plots at 60 DAS and 90 DAS and were sun dried and later dried in hot air oven at 60^{o}C for about 24 hours. The average dry weight was then recorded for each treatment.

3.6.2 Yield attributes

3.6.2.1 Number of pods per plant

The total number of pods per plant was counted from five randomly selected plants from each plot and the average number of pods per plant was recorded for each treatment.

3.6.2.2 Number of filled pods per plant

The number of filled pods per plant was counted from the five randomly selected plants and the average was recorded for each treatment.

3.6.2.3 Number of seeds per pod

Five selected plants were taken and the number of seeds per pod was counted and the average was calculated for each treatment.

3.6.2.4. Seed index (100 grain weight)

100 grains were counted from the threshed grains and their weight was recorded for each treatment.

3.6.3 Yield

3.6.3.1 Grain yield (kg ha^{-1})

The seed yield of all the plots were collected on treatment basis and the plot yield of each treatment were converted into kg ha^{-1}.

3.6.3.2 Stover yield (kg ha^{-1})

After harvest, the straw were left in each respective plots for a week for sun drying, weight of the straw (plot-wise) were taken and recorded accordingly. The plot yield was converted into kg ha^{-1}.

3.6.3.3 Harvest index

The harvest index for each treatment was calculated using the formula:

$$\text{Harvest index} = \frac{\text{Seed Yield}}{\text{Biological Yield}} \text{ x } 100$$

3.7 Plant analysis

The seeds and stovers were collected from each plot after threshing separately then sun dried and finally oven dried at 60 to 70^{o}C to attain a constant weight. The dried seeds and stover samples were then grounded to powder in a willy mill and stored in polythene bags and labelled and kept for various chemical analysis.

3.7.1. Estimation of Nitrogen in stover and seeds

Half a gram powdered sample was digested with concentrated H_2SO_4 in presence of digestion mixture ($CuSO_4$ + K_2SO_4) till the digest gave clear bluish green colour. The digested sample was further diluted carefully with distill water to known volume. Then a known volume of aliquot was transferred to distillation unit (Micro kjeldahl - apparatus) and liberated ammonia was trapped in boric acid containing mixed indicator. Later it was titrated against standard H_2SO_4 and the amount of ammonia liberated was estimated in the form of nitrogen as per the procedure given by Black (1965).

3.7.2 Digestion of plant samples for other nutrients

Half a gram powdered sample was pre-digested with concentrated HNO_3 overnight. Further predigested sample was treated with di-acid (HNO_3 : $HClO_4$ in the ratio 10 : 4) mixture and kept on hot plate for digestion till colourless thread like structures was obtained. After complete digestion precipitate was dissolved in 6*N* HCl and transferred to the 100 mL volumetric flask through Whatman No. 42

filter paper and finally the volume of extract was made to 100 mL with double distilled water and preserved for further analysis.

3.7.2.1 Estimation of Phosphorus in seeds and stover

Phosphorous in both seeds and stover was determined by vanado-molybdate yellow colour method as outlined by Jackson (1973) using spectrophotometer at 470 nm..

3.7.2.2 Estimation of Potassium in seeds and stover

Potassium in both seeds and stover was determined by flame photometry after making appropriate dilution as described by Chapman and Pratt (1961).

3.7.2.3 Estimation of Sulphur in seeds and stover

Sulphur content in seeds and stover was determined turbimetrically as described for soil sulphur (Chesnin and Yien, 1950).

3.7.3. Estimation of Boron in seeds and stover

For extraction of boron, dry ashing of the ground sample in a muffle furnace was done at 550^{0}C for 1 h and subsequent extraction with 0.36 N H_2SO_4 (Gaines and Mitchell, 1979). For boron estimation curcumin method as described by Dible *et al.,* 1954 was carried out, where 1 mL of sample aliquot and 4 mL of curcumin solution was evaporated to dryness at 55±5^{0}C. The rosocyanin colour such developed was dissolved in 95% ethanol to make the 25 mL mark in a volumetric flask. Readings were taken at 540 nm in the spectrophotometer within 2 h.

3.8 Nutrient uptake (kg ha^{-1})

The uptake of different nutrients was separately carried out in seeds and stover samples multiplying nutrient content (%) in seeds and stover samples with their corresponding yield data.

$$\text{Nutrient uptake} = \frac{\text{Yield (kg ha}^{-1}\text{) x Nutrient content(\%)}}{100}$$

3.9 Estimation of protein and oil content percentage in seeds

The protein content in seeds was calculated for each treatment by multiplying the seed N by a factor of 6.25.

Seed samples of 5 g each from all the treatments (plot wise) were taken for extraction of oil. The crushed samples were placed in a thimble and extracted with light petroleum ether for 6 hours in a soxhlet extraction unit as per method described by AOAC (1960). The extract was transferred to weight flask, the solvent distilled of and the last traces of solvent and moisture being removed by treating the flask at 100-150^0 C. Then, the flask was cooled and reweighed; the formula used for calculation of per cent oil in seed was as follows:

$$\text{Per cent oil} = \frac{(W2 - W1)}{X} \text{ x } 100$$

Where,

W_2= weight of the empty flask (g)

W_1= weight of empty flask + weight of oil (g)

X = weight of sample taken for extraction (g)

3.10 Soil analysis

Soil samples were collected from surface soil (0-15 cm) from each plot after harvest of the crop. The soil samples were then air dried and grounded and sieved through 2 mm sieve and stored in polythene bags with proper labeling for various soil analysis.

3.10.1 Soil pH

The soil pH was analyzed using Glass electrode pH meter (Richards, 1954).

3.10.2 Organic carbon

Organic carbon content in soil was determined by Rapid titration method outlined by Walkley and Black (1934) and expressed in percentage as described by Jackson (1973).

3.10.3 Electrical conductivity (EC)

The electrical conductivity (EC) was determined using Conductivity Bridge (Richards, 1954).

3.10.4 Cation exchange capacity (CEC)

The cation exchange capacity (CEC) of the soil was determined using 1 *N* NH_4OAc at pH 7.0 (Chapman, 1965).

3.10.5 Available Nitrogen

The available nitrogen in soil was determined using alkaline potassium permanganate method as described by Subbiah and Asija (1956).

3.10.6 Available Phosphorus

Available phosphorus was extracted with 0.03*N* NH_4F in *0.025N* HCl solution. The procedure is primarily meant for soils which are moderate to strongly acidic pH and determined by Bray and Kurtz method (1945).

3.10.7 Available Potassium

The available potassium in soil was determined by flame photometric method using neutral normal ammonium acetate (pH 7.0). The potassium content in the extract was determined by flame photometre (Jackson, 1973).

3.10.8 Available Sulphur

The available sulphur in soil was determined by turbidimetric method (Chesnin and Yien, 1950).

3.10.9 Exchangeable Calcium and Magnesium

The exchangeable calcium and magnesium in soil was determined by versenate method, where a known volume of soil extract was titrated with standard 0.01*N* versenate (EDTA, ethylene diamine tetra acetic acid disodium salt) solution using murexide (ammonium purpurate) indicator in the presence of NaOH solution (Black, 1965).

3.10.10 Available Boron

The available boron in soil was determined by curcumin method as described by Dible *et al*., 1954. Boron forms a reddish brown complex with curcumin, a phenol dye. After evaporation to dryness, the boron-curcumin complex was determined in ethanol at a wavelength of 540 nm using spectrophotometer.

3.10.11 Soil respiration

The soil respiration was determined using alkali entrapment method (Macfayden, 1970).

3.10.12 Soil Microbial Biomass Carbon

The soil microbial biomass carbon was determined by fumigation-extraction method (Vance *et al*., 1987).

3.11 Nutrient use efficiency (NUE)

The nutrient use efficiency (NUE) is a term used to indicate the relative balance between the amount of fertilizer taken up and used by the crop *versus* the amount of fertilizer lost.

It is calculated using the formula as follows:

$$\text{Nutrient use efficiency (\%)} = \frac{\text{Nutrient uptake in fertilized plot} - \text{Nutrient uptake in control}}{\text{Fertlizer applied}} \text{x } 100$$

3.12 Analysis of data

The collected data was processed, classified, tabulated and systematically and statistically analysed by applying the techniques of analysis of variance and the significant of different source of variations was tested by '*F*' test (Gomez and Gomez, 1984).

A

B

Plate I: A. Field preparation and layout
B. Seedling emergence

B

A

B

Plate II: A. Weeding
B. General view of the field

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS AND DISUSSION

The investigation entitled "Effect of sulphur, boron and phosphorus solubilizing biofertilizer on soybean (*Glycine max* L. Merrill) under foothill condition of Nagaland" was conducted during *kharif* season of 2016 and 2017 at the experimental research farm of Nagaland University, School of Agricultural Sciences and Rural Development (SASRD), Medziphema campus. The research site is situated at 20˚45'43" N latitude and 93˚53'04" E longitude at an altitude of 310 m above mean sea level. The experimental findings of the study are presented and discussed under the following heads:

4.1 Effect on growth attributes of soybean

The effect of sulphur, boron and phosphorus solubilizing biofertilizer on growth attributes of soybean on growth attributes *viz.* plant height, number of leaves per plant, number of nodules per plant, number of branches per plant and plant dry matter are discussed under the following headings:

4.1.1 Effect on plant height

4.1.1.1. Effect of sulphur on plant height

The results on plant height as affected by different treatments are presented in Table 4.1.1(a) and Fig. 2. As evident from the data, there was an increase in the plant height with advancement of days and appreciable difference between the various treatments. The treatment S_2 recorded the maximum plant height with corresponding value of 38.04 cm and 37.61 cm, 89.44 cm and 90.21 cm at 30 DAS and 90 DAS, respectively, while S_1 recorded the maximum height having corresponding values of 79.10 cm and 79.55 cm at 60 DAS in 2016 and 2017,

Table 4.1.1 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on plant height of soybean at different days after sowing

Treatments	**Plant height (cm)**								
	30 DAS			**60 DAS**			**90 DAS**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
$\mathbf{S_0}$	33.48	32.67	33.08	69.26	68.66	68.96	82.89	81.83	82.36
$\mathbf{S_1}$	38.04	37.43	37.74	80.00	79.10	79.55	88.36	87.94	88.15
$\mathbf{S_2}$	38.33	37.61	37.97	78.89	76.68	77.78	90.97	89.44	90.21
SEm±	***0.22***	***0.37***	***0.22***	***0.27***	***0.22***	***0.17***	***0.32***	***0.21***	***0.19***
CD(P=0.05)	***0.87***	***1.45***	***0.70***	***1.06***	***0.86***	***0.57***	***1.27***	***0.81***	***0.63***
$\mathbf{B_0}$	34.33	34.13	34.23	74.28	73.45	73.86	86.69	85.67	86.18
$\mathbf{B_1}$	37.33	36.18	36.76	74.98	73.55	74.26	86.75	86.11	86.43
$\mathbf{B_2}$	38.19	37.41	37.80	78.89	77.44	78.16	88.78	87.44	88.11
SEm±	***0.27***	***0.45***	***0.26***	***0.31***	***0.48***	***0.29***	***0.32***	***0.16***	***0.18***
CD(P=0.05)	***0.82***	***1.39***	***0.77***	***0.96***	***1.48***	***0.84***	***0.99***	***0.49***	***0.52***
$\mathbf{P_0}$	35.56	35.01	35.29	74.24	72.85	73.55	85.57	85.00	85.29
$\mathbf{P_1}$	37.67	36.80	37.24	77.85	76.78	77.31	89.24	87.81	88.53
SEm±	***0.21***	***0.27***	***0.17***	***0.28***	***0.36***	***0.23***	***0.27***	***0.20***	***0.17***
CD(P=0.05)	***0.64***	***0.82***	***0.50***	***0.83***	***1.06***	***0.65***	***0.80***	***0.59***	***0.48***

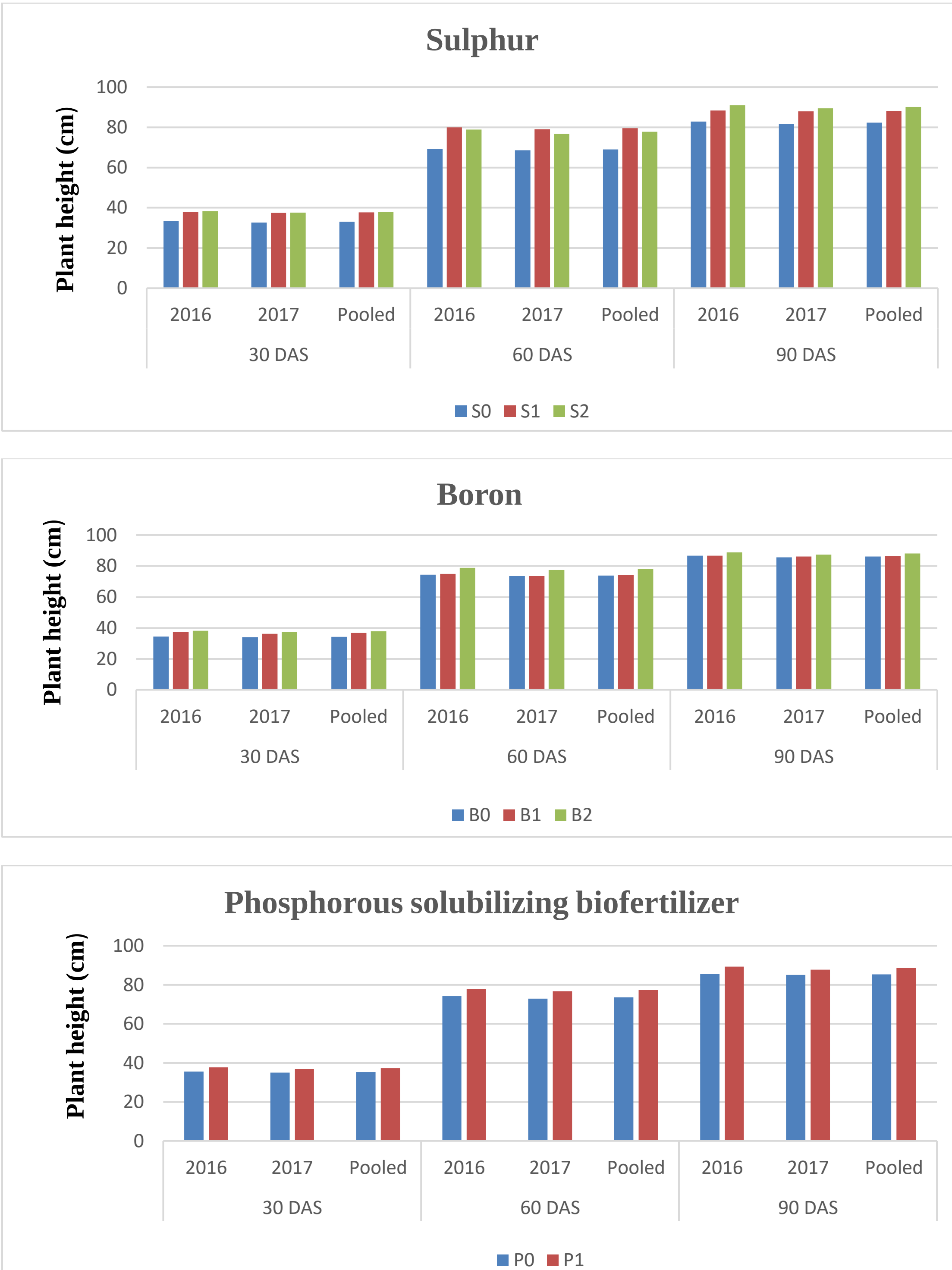


Fig.2: Effect of sulfur, boron and phosphorus solubilizing biofertilizeron plant height of soybean at different days after sowing

respectively. The pooled data showed that maximum plant height at 30 DAS and 90 DAS was observed with treatment S_2 with a corresponding value of 37.97 cm and 90.21 cm respectively while maximum plant height was observed with treatment S_1 at 60 DAS with corresponding value of 79.10 cm. The minimum plant height was observed with treatment S_0. It has been observed that application of higher dose of sulphur generally increased the plant height.

The maximum plant height recorded with application of S_2 i.e. 40 kg S ha^{-1} over other treatments might be due to the favourable effects on growth attributes as a result of better plant nutrition (Ram *et al.*, 2014). Similar findings were also reported by Najar *et al*. (2011) and Longkumer *et al*. (2017).

4.1.1.2. Effect of boron on plant height

It can be observed from the Table 4.1.1(a) and Fig. 2 that increasing application of boron increases the plant height at all stages of crop growth in both the years. Maximum plant height was recorded with application of treatment B_2 with corresponding values of 38.19 cm and 37.61 cm, 78.89 cm and 76.68 cm and 90.97 cm and 89.44 cm at 30 DAS, 60 DAS and 90 DAS, respectively in the year 2016 and 2017. The pooled data revealed that application of treatment B_2 recorded maximum plant height with corresponding value of 37.80 cm at 30 DAS, 78.16 cm at 60 DAS and 88.11 cm at 90 DAS. The data has revealed that increasing dosage of boron increases the plant height significantly.

The increased in plant height with application of treatment B_2 i.e. 2 kg B ha^{-1} might be due to the role of boron in cell division and differentiation and transport of sugars. This result is in accordance with the findings of Devi *et al*. (2012) and Longkumer *et al*. (2017).

4.1.1.3. Effect of phosphorus solubilizing biofertilizer on plant height

From Table 4.1.1(a) and Fig. 2, it can be observed that seed treatment with treatment P_1 recorded maximum plant height with corresponding value of 37.67 cm and 36.80 cm at 30 DAS, 77.85 cm and 76.78 cm at 60 DAS and 89.24 cm and 87.81 cm at 90 DAS in the year 2016 and 2017, respectively. The pooled data revealed that maximum plant height was observed with treatment P_1 with corresponding value of 37.24 cm, 77.31 cm and 88.53 cm at 30 DAS, 60 DAS and 90 DAS, respectively. From the data it can be observed that seed treatment with phosphorus solubilizing biofertilizer has a significant effect on plant height.

The increased in plant height might be due to improved apical growth as a result of growth promoting hormones production which enhanced solubilization of P, phosphatase enzyme activity and photosynthetic rates by PSB application (Raja *et al*., 2017). Pindkurwar *et al*. (2015) also reported that seed inoculation with rhizobium and phosphate solubilizing bacteria (PSB) resulted in maximum plant height. Similar findings were also reported by Rana *et al*. (2014) and Raja *et al*. (2017).

4.1.1.4. Effect of sulphur and boron interaction on plant height

From Table 4.1.1 (b), it is evident that application of treatment combination S_2B_2 recorded maximum plant height with corresponding value of 41.33 cm and 40.00 cm at 30 DAS, 83.33 cm and 80.03 cm at 60 DAS and 93.00 cm and 90.83 cm at 90 DAS in the year 2016 and 2017, respectively. The pooled data indicates that maximum plant height was observed with treatment combination S_2B_2 with corresponding value of 40.67 cm, 82.18 cm and 91.92 cm at 30 DAS, 60 DAS and 90 DAS, respectively. The minimum plant height was observed with treatment combination of S_0B_0 with corresponding value of 28.50 cm at 30 DAS, 65.32 cm

Table 4.1.1 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on plant height at different days after sowing

Treatments	Plant height (cm)								
	30 DAS			60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
S_0B_0	28.00	29.00	28.50	65.17	65.47	65.32	83.00	81.00	82.00
S_0B_1	37.37	35.33	36.35	70.60	69.20	69.90	82.67	82.00	82.33
S_0B_2	35.07	33.68	34.38	72.00	71.32	71.66	83.00	82.50	82.75
S_1B_0	38.50	37.87	38.18	81.17	80.58	80.88	88.25	87.83	88.04
S_1B_1	37.47	35.90	36.68	77.50	76.75	77.13	86.50	87.00	86.75
S_1B_2	38.17	38.53	38.35	81.33	79.97	80.65	90.33	89.00	89.67
S_2B_0	36.50	35.53	36.02	76.50	74.30	75.40	88.83	88.17	88.50
S_2B_1	37.17	37.30	37.23	76.83	74.70	75.77	91.08	89.33	90.21
S_2B_2	41.33	40.00	40.67	83.33	81.03	82.18	93.00	90.83	91.92
SEm±	***0.46***	***0.78***	***0.45***	***0.54***	***0.83***	***0.50***	***0.56***	***0.27***	***0.31***
CD(P=0.05)	***1.42***	***2.41***	***1.33***	***1.66***	***2.56***	***1.45***	***1.72***	***0.85***	***0.91***
S_0P_0	31.60	30.33	30.97	66.73	65.66	66.19	81.44	80.89	81.17
S_0P_1	35.36	35.01	35.18	71.78	71.67	71.72	84.33	82.78	83.56
S_1P_0	37.87	37.78	37.82	77.89	77.13	77.51	87.33	87.33	87.33
S_1P_1	38.22	37.09	37.66	82.11	81.07	81.59	89.39	88.56	88.97
S_2P_0	37.22	36.93	37.08	78.11	75.76	76.93	87.94	86.78	87.36
S_2P_1	39.44	38.29	38.87	79.67	77.60	78.63	94.00	92.11	93.06
SEm±	***0.37***	***0.48***	***0.30***	***0.49***	***0.62***	***0.39***	***0.46***	***0.34***	***0.29***
CD(P=0.05)	***1.10***	***1.41***	***0.86***	***1.44***	***1.83***	***1.12***	***1.38***	***1.02***	***0.83***
B_0P_0	33.56	33.58	33.57	72.44	71.39	71.92	85.67	84.56	85.11
B_0P_1	35.11	34.69	34.90	76.11	75.51	75.81	87.72	86.78	87.25
B_1P_0	36.09	35.00	35.54	73.29	71.48	72.38	85.06	84.89	84.97
B_1P_1	38.58	37.36	37.97	76.67	75.62	76.14	88.44	87.33	87.89
B_2P_0	37.04	36.47	36.76	77.00	75.68	76.34	86.00	85.56	85.78
B_2P_1	39.33	38.34	38.84	80.78	79.20	79.99	91.56	89.33	90.44
SEm±	***0.37***	***0.48***	***0.30***	***0.49***	***0.62***	***0.39***	***0.46***	***0.34***	***0.29***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***1.38***	***NS***	***0.83***

at 60 DAS and 82.00 cm, respectively. As evident from the pooled data results, treatment combination S_2B_2 was significant over all other treatment combinations.

The increased in plant height might be due to combined application of sulphur and boron which gives significantly better growth compared to application of any levels of sulphur and boron alone (Longkumer *et al*., 2017). Ram *et al*. (2014) also reported that highest growth and yield attributes in soybean were obtained with combined application of sulphur (40 kg S ha^{-1}) and boron (1.5 kg B ha^{-1}).

4.1.1.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on plant height

It is evident from Table 4.1.1 (b) that application of treatment combination S_2P_1 recorded maximum plant height with corresponding value of 39.44 cm and 38.29 cm at 30 DAS, and 94.00 cm and 92.11 cm at 90 DAS while S_1P_1 recorded 82.11 cm and 81.07 cm at 60 DAS in the year 2016 and 2017, respectively. The minimum plant height was observed with treatment combination S_0P_0 which recorded 31.60 cm and 30.33 cm at 30 DAS, 66.73 cm and 65.66 cm at 60 DAS, and 81.44 cm and 80.89 cm at 90 DAS, respectively in the year 2016 and 2017. The pooled data revealed that maximum plant height was observed with treatment combination S_2P_1 with recorded value of 38.87 cm at 30 DAS, and 93.06 cm at 90 DAS whereas treatment combination S_1P_1 recorded 81.59 cm at 60 DAS. Application of different levels of sulphur alone was found to increase the plant height. However, when combined together with seed treatment of phosphorus solubilizing biofertilizer, it was found that the plant height increased even more significantly.

Dhage *et al*. (2014) reported that sulphur and phosphorus have synergistic effect on growth and yield of soybean. This might be due to better plant development as a result of well developed root system and nodules through better plant nutrient utilization (Dhage *et al*., 2014 and Suman *et al*., 2018).

4.1.1.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on plant height

As evident from Table 4.1.1 (b), treatment combination B_2P_1 recorded maximum plant height with corresponding value of 39.33 cm and 38.34 cm at 30 DAS, 80.78 cm and 79.20 cm at 60 DAS, and 91.56 cm and 89.33 cm at 90 DAS, respectively in the year 2016 and 2017. The minimum plant height was observed with treatment combination B_0P_0 which recorded 33.56 cm and 33.58 cm at 30 DAS, 72.44 cm and 71.39 cm at 60 DAS, and 85.67 cm and 84.56 cm at 90 DAS, respectively in the year 2015 and 2016. From the pooled data it is evident that treatment combination of B_2P_1 recorded maximum plant height with recorded value of 38.84 cm at 30 DAS, 79.99 cm at 60 DAS and 90.44 cm at 90 DAS. It was observed that the treatment combinations of boron and phosphorus solubilizing biofertilizer did not have significant interaction effect on plant height at 30 and 60 DAS. However, at 90 DAS it was observed that the interaction between boron and phosphorus solubilizing biofertilizer had a significant effect on plant height.

The results revealed that increased in plant height becomes more evident when boron fertilization was applied together with phosphorus solubilizing biofertilizer. The finding is in agreement with the observation of Kamboj *et al.* (2018) who reported that application of phosphorus increases plant height and application with or without boron produced similar plant heights in soybean.

Sentimenla *et al*. (2012) also reported that combined application phosphorus and boron recorded the maximum plant height in soybean.

4.1.1.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on plant height

As evident from Table 4.1.1 (c), the treatment combination of $S_2B_2P_1$ recorded maximum plant height with corresponding value of 42.33 cm and 41.67 cm at 30 DAS, 84.33 cm and 82.07 cm at 60 DAS, and 97.33 cm and 94.67 cm at 90 DAS while the minimum plant height was observed with treatment combination $S_0B_0P_0$ with recorded value of 26.33 cm and 27.00 cm at 30 DAS, 64.67 cm and 63.87 cm at 60 DAS, and 82.33 cm and 80.67 cm at 90 DAS in the year 2016 and 2017, respectively. The results from the pooled data revealed that maximum plant height was observed treatment combination $S_2B_2P_1$ with recorded value of 42.00 cm at 30 DAS, 83.20 cm at 60 DAS, and 96.00 cm at 90.00 cm at 90 DAS. The results revealed that $S_2B_2P_1$ interactions shows significant effect on plant height over other treatment combinations at all stages of crop growth.

Longkumer *et al.* (2017) reported that combined application of 40 kg S ha^{-1} with either 1.0 or 1.5 kg B ha^{-1} have significant interaction effect on growth attributes of soybean. The increased in plant height could be due to improved plant nutrition through sulphur and boron application along with phosphorus solubilizing biofertilizer which solubilizes the insoluble phosphate to soluble form for plant uptake resulting in better root development and better utilization of nutrients from the soil.

Table 4.1.1 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on plant height at different days after sowing

Treatments	Plant height (cm)								
	30 DAS			60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
$S_0B_0P_0$	26.33	27.00	26.67	64.67	63.87	64.27	82.33	80.67	81.50
$S_0B_0P_1$	29.67	31.00	30.33	65.67	67.07	66.37	83.67	81.33	82.50
$S_0B_1P_0$	34.67	32.33	33.50	67.53	65.67	66.60	82.00	80.33	81.17
$S_0B_1P_1$	40.07	38.33	39.20	73.67	72.73	73.20	83.33	83.67	83.50
$S_0B_2P_0$	33.80	31.67	32.73	68.00	67.43	67.72	80.00	81.67	80.83
$S_0B_2P_1$	36.33	35.70	36.02	76.00	75.20	75.60	86.00	83.33	84.67
$S_1B_0P_0$	38.67	38.93	38.80	77.33	77.10	77.22	87.00	86.00	86.50
$S_1B_0P_1$	38.33	36.80	37.57	85.00	84.07	84.53	89.50	89.67	89.58
$S_1B_1P_0$	37.93	35.00	36.47	75.67	74.70	75.18	85.67	88.00	86.83
$S_1B_1P_1$	37.00	36.80	36.90	79.33	78.80	79.07	87.33	86.00	86.67
$S_1B_2P_0$	37.00	39.40	38.20	80.67	79.60	80.13	89.33	88.00	88.67
$S_1B_2P_1$	39.33	37.67	38.50	82.00	80.33	81.17	91.33	90.00	90.67
$S_2B_0P_0$	35.67	34.80	35.23	75.33	73.20	74.27	87.67	87.00	87.33
$S_2B_0P_1$	37.33	36.27	36.80	77.67	75.40	76.53	90.00	89.33	89.67
$S_2B_1P_0$	35.67	37.67	36.67	76.67	74.07	75.37	87.50	86.33	86.92
$S_2B_1P_1$	38.67	36.93	37.80	77.00	75.33	76.17	94.67	92.33	93.50
$S_2B_2P_0$	40.33	38.33	39.33	82.33	80.00	81.17	88.67	87.00	87.83
$S_2B_2P_1$	42.33	41.67	42.00	84.33	82.07	83.20	97.33	94.67	96.00
SEm±	***0.64***	***0.82***	***0.52***	***0.84***	***1.07***	***0.68***	***0.81***	***0.59***	***0.50***
CD(P=0.05)	***1.91***	***2.45***	***1.50***	***2.50***	***3.17***	***1.95***	***2.39***	***1.76***	***1.43***

4.1.2 Effect on number of leaves per plant

4.1.2.1. Effect of sulphur on number of leaves per plant

As evident from Table 4.1.2 (a), the highest number of leaves was observed with application of S_2 (40 kg S ha^{-1}) which recorded 8.08 and 8.00 leaves per plant at 30 DAS, 26.52 and 25.72 leaves per plant at 60 DAS, and 32.69 and 31.42 leaves per plant at 90 DAS in the year 2016 and 2017, respectively. The lowest number of leaves per plant was observed with S_0 (control) which recorded 7.39 and 6.83 leaves per plant at 30 DAS, 24.22 and 23.03 leaves per plant at 60 DAS, and 29.89 and 29.25 leaves per plant at 60 DAS. From the pooled data it is apparent that treatment S_2 (40 kg S ha^{-1}) recorded maximum number of leaves per plant with recorded value of 8.04 at 30 DAS, 26.12 at 60 DAS and 32.06 at 90 DAS. At 30 DAS and 60 DAS, treatment S_1 was statistically at par with S_2. However, towards later stages of growth, treatment S_2 (40 kg S ha^{-1}) was significant over other treatments. This could be due to better root development resulting in higher nutrient uptake at later stages of growth.

The results are in concurrence with the findings of Devi *et al*. (2012) who reported that application of different levels of sulphur had a significant influence on growth and yield attributes of soybean. Ram *et al*. (2014) also reported that application of 40 kg S ha^{-1} recorded significantly better growth and yield attributes of soybean.

4.1.2.2. Effect of boron on number of leaves per plant

The results on the number of leaves per plant have been presented in Table 4.1.2 (a). The number of leaves per plant was higher in plants receiving treatment B_2 (2 kg B ha^{-1}) with recorded value of 8.45 and 7.89 at 30 DAS, 25.17 at 60 DAS, and 31.72 and 30.81 at 90 DAS during 2016 and 2017 as compared to other

Table 4.1.2 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on number of leaves at different days after sowing

Treatments	**Number of leaves plant^{-1}**								
	30 DAS			**60 DAS**			**90 DAS**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	7.39	6.83	7.11	24.22	23.03	23.63	29.89	29.25	29.57
S_1	7.92	7.67	7.79	25.71	24.82	25.26	30.89	29.58	30.24
S_2	8.08	8.00	8.04	26.52	25.72	26.12	32.69	31.42	32.06
SEm±	***0.25***	***0.22***	***0.17***	***0.21***	***0.34***	***0.20***	***0.51***	***0.15***	***0.27***
CD(P=0.05)	***NS***	***0.87***	***0.54***	***0.82***	***1.34***	***0.65***	***2.01***	***0.59***	***0.87***
B_0	7.20	7.22	7.21	24.53	23.54	24.04	30.03	29.19	29.61
B_1	7.73	7.39	7.56	26.01	24.86	25.43	31.72	30.25	30.99
B_2	8.45	7.89	8.17	25.91	25.17	25.54	31.72	30.81	31.26
SEm±	***0.21***	***0.24***	***0.16***	***0.27***	***0.37***	***0.23***	***0.22***	***0.26***	***0.17***
CD(P=0.05)	***0.63***	***NS***	***0.46***	***0.83***	***1.14***	***0.67***	***0.68***	***0.81***	***0.50***
P_0	7.58	7.15	7.36	24.58	23.42	24.00	29.22	28.19	28.70
P_1	8.01	7.85	7.93	26.39	25.63	26.01	33.09	31.98	32.54
SEm±	***0.24***	***0.19***	***0.15***	***0.20***	***0.24***	***0.15***	***0.31***	***0.27***	***0.20***
CD(P=0.05)	***NS***	***0.57***	***0.44***	***0.59***	***0.70***	***0.44***	***0.91***	***0.81***	***0.59***

treatments at all stages of growth except at 60 DAS during 2016 which was highest with treatment B_1 having 26.01 leaves per plant. The lowest number of leaves per plant was observed with control (B_0) treatment. The pooled data revealed that the maximum number of leaves per plant was highest with application of treatment B_2 with corresponding value of 8.17 at 30 DAS, 25.54 at 60 DAS and 31.26 at 90 DAS. The treatment B_2 was found to be significant over other treatments at 30 DAS. However, at 60 and 90 DAS, treatment B_1 was found to be statistically at par with treatment B_2.

Rajendran *et al*. (2012) reported that significantly higher growth and yield attributes were obtained with application of boron @ 1 kg B ha^{-1} in soybean. The increased in the number of leaves might be due to the fact that boron plays a pivotal role in cell differentiation and development (Devi *et al*., 2012).

4.1.2.3. Effect of phosphorus solubilizing biofertilizer on number of leaves per plant

As shown in Table 4.1.2. (a), in general seed treatment with phosphorus solubilizing biofertilizer improves the number of leaves per plant over control treatment. The highest number of leaves per plant was observed with treatment P_1 with value of 8.01 and 7.85 at 30 DAS, 26.39 and 25.63 at 60 DAS and 33.09 and 31.98 at 90 DAS during the year 2016 and 2017, respectively. From the pooled data, the results indicate that the number of leaves per plant was found to be significant with treatment P_1 over control treatment with corresponding value of 7.93 at 30 DAS, 26.01 at 60 DAS, and 32.54 at 90 DAS.

The higher number of leaves per plant might be due to higher availability of phosphorus which helps in root development as a result of phosphorus solubilizing biofertilizer (PSB) application which solubilizes the insoluble phosphate in the soil contributing to better plant growth and thus higher number of leaves. Pindkurwar *et al*. (2015) revealed that combined application of *Rhizobium* + PSB + RDF increased the number of functional leaves per plant in soybean.

4.1.2.4. Effect of sulphur and boron interaction on number of leaves per plant

The interaction effect of sulphur and boron on the number of leaves per plant has been presented on Table 4.1.2 (b). The maximum number of leaves per plant was observed in plants receiving treatment combination S_2B_2 which recorded 9.17 and 8.67 at 30 DAS, 28.00 and 27.17 at 60 DAS, and 34.50 and 34.08 at 90 DAS both in the year 2016 and 2017, respectively. The lowest number of leaves per plant was observed with control treatment (S_0B_0) having 6.93 and 6.17 at 30 DAS 23.27 and 21.50 at 60 DAS, and 29.17 and 29.08 at 90 DAS in the year 2016 and 2017, respectively. The pooled data revealed that the highest number of leaves was recorded with treatment combination S_2B_2 which recorded 8.92, 27.17 and 34.29 at 30, 60 and 90 DAS respectively. As apparent from the results, the different treatment combinations did not have any significant effect on the number of leaves per plant at 30 DAS. However, at 60 and 90 DAS, the treatment combinations showed significant effect on the number of leaves per plant.

Longkumer *et al*. (2017) revealed that combined application of 40 kg S ha^{-1} with either 1.0 or 1.5 kg B ha^{-1} have significant interaction effect with the maximum growth responses.

4.1.2.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on number of leaves per plant

The results on the interaction effect of sulphur and phosphorus solubilizing biofertilizer on the number of leaves per plant have been presented on Table 4.1.2. (b). At 30 DAS, the maximum number of leaves was observed with

Table 4.1.2 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on number of leaves at different days after sowing

Treatments	Number of leaves plant^{-1}								
	30 DAS			60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
S_0B_0	6.93	6.17	6.55	23.27	21.50	22.38	29.17	29.08	29.13
S_0B_1	7.30	6.83	7.07	24.67	23.42	24.04	31.50	30.25	30.88
S_0B_2	7.93	7.50	7.72	24.73	24.17	24.45	29.00	28.42	28.71
S_1B_0	7.40	8.00	7.70	24.67	24.03	24.35	29.50	28.92	29.21
S_1B_1	8.10	7.50	7.80	27.47	26.23	26.85	31.50	29.92	30.71
S_1B_2	8.25	7.50	7.88	24.98	24.18	24.58	31.67	29.92	30.79
S_2B_0	7.27	7.50	7.38	25.67	25.08	25.38	31.42	29.58	30.50
S_2B_1	7.80	7.83	7.82	25.90	24.92	25.41	32.17	30.58	31.38
S_2B_2	9.17	8.67	8.92	28.00	27.17	27.58	34.50	34.08	34.29
SEm±	***0.36***	***0.41***	***0.27***	***0.47***	***0.64***	***0.40***	***0.38***	***0.46***	***0.30***
CD(P=0.05)	***NS***	***NS***	***NS***	***1.43***	***1.98***	***1.16***	***1.19***	***1.41***	***0.87***
S_0P_0	7.00	6.22	6.61	23.38	21.89	22.63	28.33	27.17	27.75
S_0P_1	7.78	7.44	7.61	25.07	24.17	24.62	31.44	31.33	31.39
S_1P_0	7.69	7.44	7.57	24.98	23.87	24.42	29.22	28.11	28.67
S_1P_1	8.14	7.89	8.02	26.43	25.77	26.10	32.56	31.06	31.81
S_2P_0	8.04	7.78	7.91	25.38	24.50	24.94	30.11	29.28	29.69
S_2P_1	8.11	8.22	8.17	27.67	26.94	27.31	35.28	33.56	34.42
SEm±	***0.41***	***0.33***	***0.26***	***0.34***	***0.41***	***0.27***	***0.53***	***0.47***	***0.35***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
B_0P_0	6.73	6.78	6.76	23.44	22.36	22.90	28.11	27.28	27.69
B_0P_1	7.67	7.67	7.67	25.62	24.72	25.17	31.94	31.11	31.53
B_1P_0	7.82	7.33	7.58	25.53	23.83	24.68	29.67	28.56	29.11
B_1P_1	7.64	7.44	7.54	26.49	25.88	26.18	33.78	31.94	32.86
B_2P_0	8.18	7.33	7.76	24.76	24.07	24.41	29.89	28.72	29.31
B_2P_1	8.72	8.44	8.58	27.06	26.28	26.67	33.56	32.89	33.22
SEm±	***0.41***	***0.33***	***0.26***	***0.34***	***0.41***	***0.27***	***0.53***	***0.47***	***0.35***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***

treatment combination S_1P_1 at in 2016 which recorded 8.14 while in 2017, the maximum was recorded with S_2P_1 which was 8.22. At 60 and 90 DAS, the maximum number of leaves per plant was observed with treatment combination S_2P_1 which recorded 27.67 and 26.94, and 35.28 and 33.56, respectively during 2016 and 2017. The lowest was recorded with control treatment (S_0P_0). From the pooled data as presented in Table 5, treatment combination S_2P_1 recorded the highest number of leaves per plant with corresponding value of 8.17 at 30 DAS, 27.31 at 60 DAS, and 34.42 at 90 DAS. There was no significant interaction effect of sulphur and phosphorus solubilizing biofertilizer on the number of leaves per plant.

4.1.2.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on number of leaves per plant

The interaction effect of boron and phosphorus solubilizing biofertilizer on the number of leaves per plant has been presented on Table 4.1.2 (b). As evident from the results, the highest number of leaves per plant was observed with treatment combination B_2P_1 with corresponding value of 8.72 and 8.44 at 30 DAS and 27.06 and 26.28 at 60 DAS during 2016 and 2017. However, at 90 DAS, the highest number of leaves per plant was observed with treatment B_1P_1 during 2016 which was 33.78 while during 2017 treatment B_2P_1 which recorded 32.89. The lowest number of leaves per plant was observed with control treatment (B_0P_0) in both the years. The pooled data revealed that treatment combination B_2P_1 recorded the highest number of leaves per plant with corresponding value of 8.56 at 30 DAS, 26.67 at 60 DAS and 33.22 at 90 DAS. It was observed that there was no significant interaction effect between boron and phosphorus solubilizing biofertilizer on the number of leaves per plant at all stage of growth. Timotiwu *et* *al*. (2018) confirmed that the growth response of soybean to increased phosphorus application was independent of boron fertilization.

4.1.2.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on the number of leaves per plant

The overall interaction effect of sulphur, boron and phosphorus solubilizing biofertilizer on the number of leaves per plant have been presented on Table 4.1.2 (c). As evident from the results, treatment combination $S_2B_2P_1$ recorded the highest number of leaves per plant with corresponding value of 9.33 and 9.00 at 30 DAS, 28.67 and 28.00 at 60 DAS, and 36.67 and 35.50 at 90 DAS at all stages of growth both in year 2016 and 2017. The lowest number of leaves per plant was observed with treatment combination $S_0B_0P_0$ having corresponding value of 6.00 and 5.33 at 30 DAS, 22.67 and 20.67 at 60 DAS, and 28.00 and 27.33 at 90 DAS, respectively in the year 2016 and 2017. The pooled data revealed that treatment combination $S_2B_2P_1$ recorded the highest number of leaves per plant with corresponding value of 9.17, 28.33 and 36.06 at 30, 60 and 90 DAS respectively. As apparent from the results, there was no significant interaction effect on number of leaves per plant at 30 and 60 DAS. However, towards later stage of growth significant interaction effect was observed at 90 DAS. Treatment $S_2B_2P_1$ was observed to be significant over other treatment combinations. From the pooled data, treatment $S_0B_1P_1$, $S_1B_2P_1$, $S_2B_0P_1$, $S_2B_1P_1$ and $S_2B_2P_0$ were at par with each other.

Longkumer *et al*. (2017) revealed that combined application of 40 kg S ha^{-1} with either 1.0 or 1.5 kg B ha^{-1} have significant interaction effect with the maximum growth responses. Ram *et al*. (2014) revealed that application of 40 kg S ha^{-1} recorded significantly better growth and yield attributes of soybean. The increased in the number of leaves might be due to the fact that boron plays a

Table 4.1.2 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on number of leaves at different days after sowing

Treatments	Number of leaves plant^{-1}								
	30 DAS			60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
$S_0B_0P_0$	6.00	5.33	5.67	22.67	20.67	21.67	28.00	27.33	27.67
$S_0B_0P_1$	7.87	7.00	7.43	23.87	22.33	23.10	30.33	30.83	30.58
$S_0B_1P_0$	7.20	6.67	6.93	24.00	22.00	23.00	28.67	27.83	28.25
$S_0B_1P_1$	7.40	7.00	7.20	25.33	24.83	25.08	34.33	32.67	33.50
$S_0B_2P_0$	7.80	6.67	7.23	23.47	23.00	23.23	28.33	26.33	27.33
$S_0B_2P_1$	8.07	8.33	8.20	26.00	25.33	25.67	29.67	30.50	30.08
$S_1B_0P_0$	7.27	8.00	7.63	23.73	23.07	23.40	28.33	28.00	28.17
$S_1B_0P_1$	7.53	8.00	7.77	25.60	25.00	25.30	30.67	29.83	30.25
$S_1B_1P_0$	8.07	7.33	7.70	27.73	25.67	26.70	30.33	29.17	29.75
$S_1B_1P_1$	8.13	7.67	7.90	27.20	26.80	27.00	32.67	30.67	31.67
$S_1B_2P_0$	7.73	7.00	7.37	23.47	22.87	23.17	29.00	27.17	28.08
$S_1B_2P_1$	8.77	8.00	8.38	26.50	25.50	26.00	34.33	32.67	33.50
$S_2B_0P_0$	6.93	7.00	6.97	23.93	23.33	23.63	28.00	26.50	27.25
$S_2B_0P_1$	7.60	8.00	7.80	27.40	26.83	27.12	34.83	32.67	33.75
$S_2B_1P_0$	8.20	8.00	8.10	24.87	23.83	24.35	30.00	28.67	29.33
$S_2B_1P_1$	7.40	7.67	7.53	26.93	26.00	26.47	34.33	32.50	33.42
$S_2B_2P_0$	9.00	8.33	8.67	27.33	26.33	26.83	32.33	32.67	32.50
$S_2B_2P_1$	9.33	9.00	9.17	28.67	28.00	28.33	36.67	35.50	36.08
SEm±	***0.71***	***0.58***	***0.46***	***0.60***	***0.71***	***0.46***	***0.92***	***0.81***	***0.61***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***2.73***	***2.42***	***1.76***

pivotal role in cell differentiation and development (Devi *et al*., 2012). Pindurkwar *et al*. (2015) also revealed that combined application of *Rhizobium* + PSB + RDF increased the number of functional leaves per plant in soybean.

4.1.3 Effect on number of nodules per plant

4.1.3.1. Effect of sulphur on number of nodules per plant

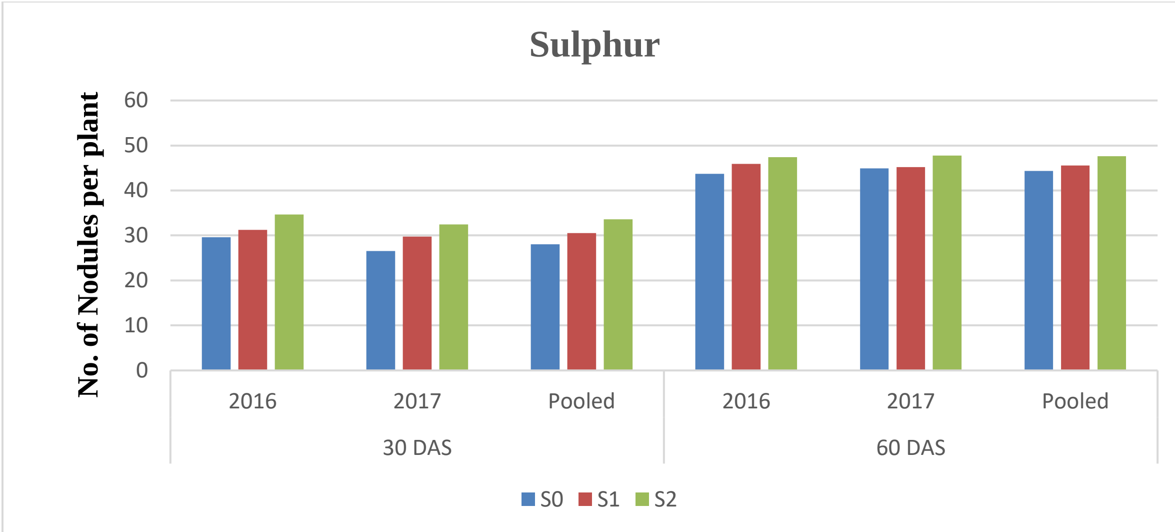
The effect of sulphur on the number of nodules per plant has been presented in Table 4.1.3(a) and Fig. 3. From the results it was apparent that increasing the dose of sulphur increases the number of nodules per plant. Application of S_2 (40 kg S ha^{-1}) recorded the highest number of nodules with corresponding values of 34.69 and 32.44 at 30 DAS, and 47.44 and 47.78 at 60 DAS while the lowest number of nodules per plant was observed with S_0 (0 kg S ha^{-1}) which recorded 29.58 and 26.56 at 30 DAS, and 43.67 and 44.94 at 60 DAS during 2016 and 2017, respectively. The pooled data revealed that application of S_2 significantly increased the number of nodules per plant over treatment S_0 and S_1 which recorded 33.57 at 30 DAS and 47.61 at 60 DAS.

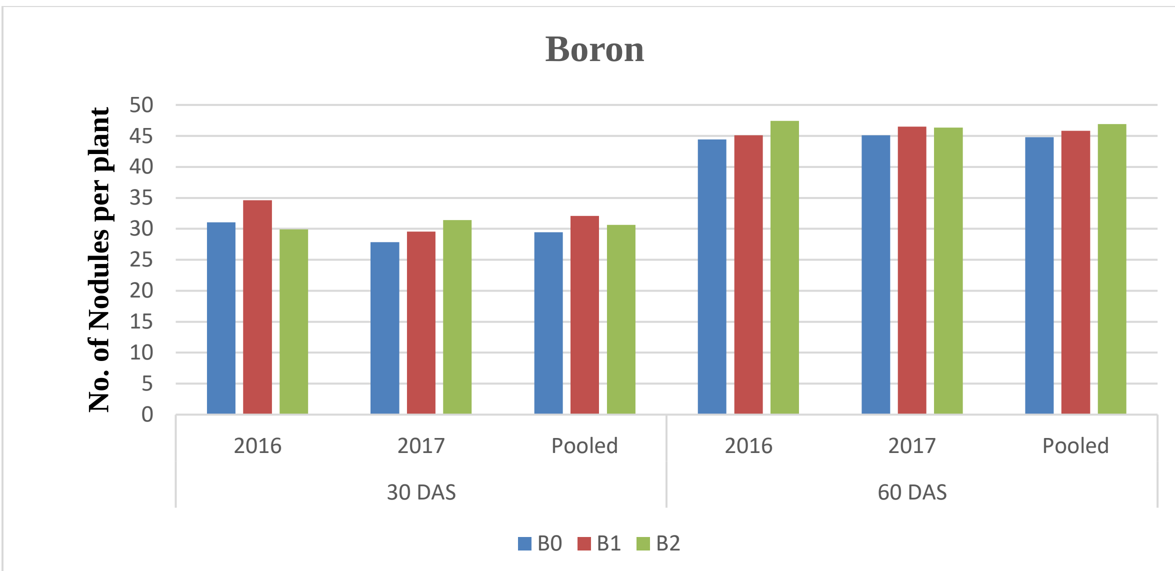
Najar *et al*. (2011) observed that increasing the levels of sulphur fertilization up to 40 kg S ha^{-1} significantly increases the nodulation in soybean which might be due to the essentiality of sulphur in nitrogenase enzyme activity responsible for root nodulation and nitrogen fixation in legumes. Similar finding on the number of nodules per plant was also reported Lakshman *et al*. (2015). Ganeshamurthy (1996) and Chaurasia *et al*. (2009) also reported application of 40 kg S ha^{-1} significantly increased the root nodulation in soybean.

Table 4.1.3 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on number of nodules at different days after sowing

Treatments	**Number of nodules plant^{-1}**					
	30 DAS			**60 DAS**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	29.58	26.56	28.07	43.67	44.94	44.31
S_1	31.28	29.78	30.53	45.89	45.22	45.56
S_2	34.69	32.44	33.57	47.44	47.78	47.61
SEm±	***0.34***	***0.21***	***0.20***	***0.14***	***0.12***	***0.09***
CD(P=0.05)	***1.35***	***0.84***	***0.66***	***0.56***	***0.45***	***0.30***
B_0	31.04	27.83	29.44	44.44	45.11	44.78
B_1	34.59	29.56	32.08	45.11	46.50	45.81
B_2	29.92	31.39	30.66	47.44	46.33	46.89
SEm±	***0.43***	***0.25***	***0.25***	***0.13***	***0.17***	***0.11***
CD(P=0.05)	***1.34***	***0.77***	***0.73***	***0.41***	***0.51***	***0.31***
P_0	30.86	27.52	29.19	44.37	44.56	44.46
P_1	32.84	31.67	32.26	46.96	47.41	47.19
SEm±	***0.54***	***0.18***	***0.29***	***0.11***	***0.17***	***0.10***
CD(P=0.05)	***1.61***	***0.54***	***0.82***	***0.33***	***0.50***	***0.29***

\





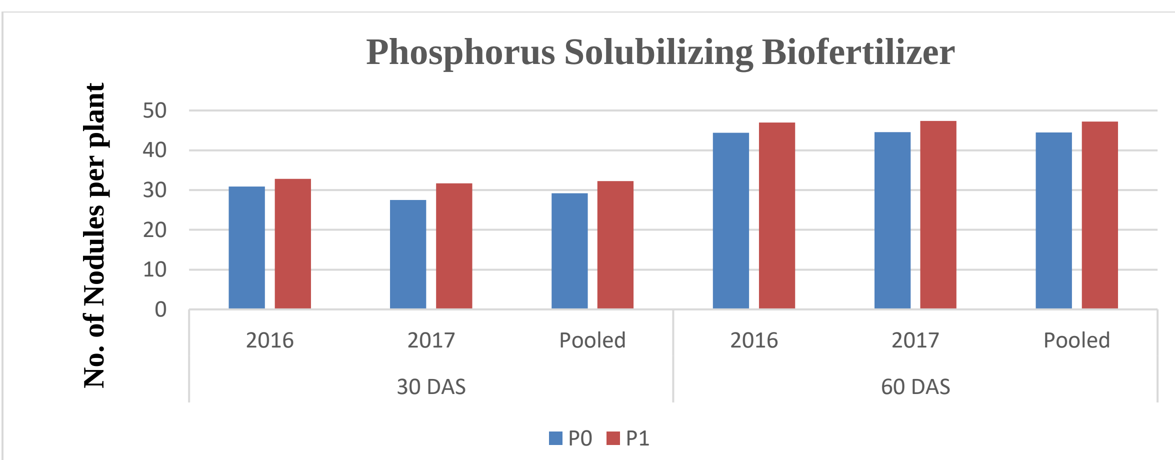


Fig. 3: Effect of sulfur, boron and phosphorus solubilizing biofertilizeron number of nodules at different days after sowing

4.1.3.2. Effect of boron on number of nodules per plant

As evident from the Table 4.1.3(a) and Fig. 3, application of B_1 recorded the highest number of nodules per plant at 30 DAS during 2016 which was 34.59 while during 2017 B_2 recorded the highest number of nodules having 31.39 nodules per plant. At 60 DAS, treatment B_2 recorded the highest with 47.44 numbers of nodules per plant during 2016 while in 2017 treatment B_1 recorded the highest having 46.50 nodules per plant. The pooled data results revealed that application of treatment B_1 recorded the highest nodules with 32.08 nodules per plant at 30 DAS while at 60 DAS the highest nodules were recorded with treatment B_2 having 46.89 nodules per plant. Application of treatment B_1 significantly gives higher number of nodules per plant at 30 DAS while treatment B_2 gives significantly higher number of nodules per plant at 60 DAS than B_0 (control) and B_1 (1 kg B ha^{-1}).

The increased in the number of nodules per plant might be due to boron nutrition which enhanced *Rhizobium* activity (Chaithra and Hebsur, 2018). Rahman *et al*. (1999) also observed that boron application has significant effect on root nodulation in soybean. Similar findings on rood nodulation with boron fertilization were also reported by Longkumer *et al*. (2017) and Sentimenla *et al*. (2012).

4.1.3.3. Effect of phosphorus solubilizing biofertilizer on number of nodules per plant

The effect of phosphorus solubilizing biofertlizer on the number of nodules per plant has been presented in Table 4.1.3 (a) and Fig. 3. As evident from the results obtained, seed inoculation with phosphorus solubilizing biofertilizer (P_1) recorded the highest number of nodules having 32.84 and 31.67 nodules per plant at 30 DAS, and 46.96 and 47.41 nodules per plant at 60 DAS during 2016 and 2017, respectively. The uninoculated seeds *i*.e., P_0 recorded lower number of nodules having 30.86 and 27.52 at 30 DAS, and 44.37 and 44.56 at 60 DAS during 2016 and 2017, respectively. The pooled data revealed that application of phosphorus solubilizing biofertilizer (P_1) significantly gives higher nodules per plant with corresponding value of 32.26 and 47.19 compared to the control treatment (P_0) having an average of 29.19 and 44.46 nodules per plant at 30 and 60 DAS, respectively.

The increased in root nodulation with application of phosphorus solubilizing biofertilizer might be due improved P availability in soil and enhanced symbiotic N_2 fixation (Gupta *et al*., 1998). The results are in accordance with the observations of Dhage *et al*. (2008) who reported that the number of nodules per plant in soybean significantly increased by seed inoculation with *Rhizobium* and PSB.

4.1.3.4. Effect of sulphur and boron interaction on the number of nodules per plant

The interaction effect of sulphur and boron on the number of nodules per plant has been presented on Table 4.1.3 (b). It was observed that application of S_2B_1 gives the highest number of nodules per plant (38.08) at 30 DAS during 2016 while S_2B_2 gives the highest number of nodules per plant (34.50) at 30 DAS during 2017. The lowest number of nodules per plant was observed with S_0B_2 which recorded 26.72 nodules per plant during 2016 while S_0B_0 recorded the lowest having 24.83 nodules per plant at 30 DAS during 2017. At 60 DAS the highest number of nodules per plant was observed with treatment combination S_2B_2 having 49.50 and 49.17 nodules per plant during the year 2016 and 2017, respectively. The lowest number of nodules per plant at 60 DAS was observed

Table 4.1.3 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer on interaction number of nodules at different days after sowing

Treatments	Number of nodules plant^{-1}					
	30 DAS			60 DAS		
	2016	2017	Pooled	2016	2017	Pooled
S_0B_0	28.93	24.83	26.88	41.67	43.33	42.50
S_0B_1	33.43	27.00	30.22	43.50	46.83	45.17
S_0B_2	26.72	27.83	27.28	45.83	44.67	45.25
S_1B_0	28.30	28.67	28.48	46.33	45.00	45.67
S_1B_1	32.27	28.83	30.55	44.33	45.50	44.92
S_1B_2	33.28	31.83	32.56	47.00	45.17	46.08
S_2B_0	36.23	30.00	33.12	45.33	47.00	46.17
S_2B_1	38.08	32.83	35.46	47.50	47.17	47.33
S_2B_2	29.77	34.50	32.13	49.50	49.17	49.33
SEm±	***0.83***	***0.43***	***0.47***	***0.23***	***0.29***	***0.18***
CD(P=0.05)	***2.56***	***1.33***	***1.37***	***0.71***	***0.89***	***0.54***
S_0P_0	28.90	25.33	27.12	42.67	43.67	43.17
S_0P_1	30.49	27.78	29.13	44.67	46.22	45.44
S_1P_0	31.66	27.22	29.44	44.56	43.89	44.22
S_1P_1	30.91	32.33	31.62	47.22	46.56	46.89
S_2P_0	32.26	30.00	31.13	45.89	46.11	46.00
S_2P_1	37.13	34.89	36.01	49.00	49.44	49.22
SEm±	***0.95***	***0.31***	***0.50***	***0.19***	***0.29***	***0.18***
CD(P=0.05)	***2.83***	***0.93***	***1.44***	***NS***	***NS***	***NS***
B_0P_0	30.80	26.22	28.51	42.89	43.78	43.33
B_0P_1	31.51	29.44	30.48	46.00	46.44	46.22
B_1P_0	31.89	27.56	29.72	44.78	45.56	45.17
B_1P_1	37.30	31.56	34.43	45.44	47.44	46.44
B_2P_0	30.12	28.78	29.45	45.44	44.33	44.89
B_2P_1	29.72	34.00	31.86	49.44	48.33	48.89
SEm±	***0.95***	***0.31***	***0.50***	***0.19***	***0.29***	***0.18***
CD(P=0.05)	***2.83***	***0.93***	***1.44***	***0.57***	***0.87***	***0.50***

with S_0B_0 which recorded 41.67 and 43.33 nodules per plant during 2016 and 2017, respectively.

As evident from the results obtained in pooled data, the highest number of nodules per plant at 30 DAS was observed with application of S_2B_1 which recorded 35.46 nodules per plant on an average. At 60 DAS, application of S_2B_2 gives the highest number of nodules which recorded 49.33 nodules per plant. The lowest number of nodules was observed with S_0B_0 having 26.88 and 42.50 nodules per plant at 30 and 60 DAS, respectively. It was observed that increasing the level of sulphur increased the number of nodules but when applied together with boron gives higher number of nodules per plant.

The increase in the number of nodules per plant can be attributed to the fact that root nodulation and biological N_2 fixation in soybean are influenced by both sulphur and boron. The results are in accordance with findings of Longkumer *et al*. (2017) who opined that application of S (40 kg ha^{-1}) and B (1.5 kg ha^{-1}) have synergistic interaction effect with the highest number of nodules per plant in soybean.

4.1.3.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on the number of nodules per plant

The results of interaction effect of sulphur and phosphorus solubilizing biofertilizer on the number of nodules per plant have been presented on Table 4.1.3 (b). The two years data revealed that application of S_2P_1 gives the highest number of nodules per plant which recorded 37.13 and 34.89 at 30 DAS, and 49.00 and 49.44 at 60 DAS during 2016 and 2017, respectively. The lowest number of nodules per plant was obtained with S_0P_0 (control) which recorded 28.90 and 25.33 at 30 DAS, and 42.67 and 43.67 at 60 DAS during 2016 and

2017, respectively. The pooled data revealed that the highest number of nodules per plant was obtained with application of S_2P_1 which recorded 36.01 at 30 DAS and 49.22 at 60 DAS while the lowest was recorded with S_0P_0 which recorded 27.12 and 43.17 at 30 and 60 DAS, respectively. It was observed that increasing the level of sulphur alone increased the number of nodules per plant. However, when sulphur was applied in conjunction with phosphorus solubilizing biofertilizer as seed treatment further increases the nodules. The treatment combination S_2P_1 was found to be significant over other treatment combinations.

The increased in the number of nodules per plant could be due to improved P availability in soil which enhanced symbiotic N_2 fixation through PSB (Gupta *et al*., 1998) and also due to the role of sulphur in nitrogenase enzyme activity responsible for root nodulation and nitrogen fixation in legumes (Najar *et al*., 2011), as a result of sulphur and phosphorus solubilizing biofertilizer application. Lalitlanmawia *et al*. (2005) also concluded that P and S application significantly increases the number of nodules per plant in soybean.

4.1.3.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on the number of nodules per plant

From Table 4.1.3 (b), it was evident that at 30 DAS the highest number of nodules per plant during 2016 was obtained from B_1P_1 with an average of 37.30 nodules per plant, while during 2017 B_2P_1 recorded the highest with 34.00 nodules per plant. At 60 DAS, treatment combination B_2P_1 recorded the highest number of nodules per plant which recorded 49.44 and 48.33 nodules per plant during 2016 and 2017, respectively. As apparent from the pooled data, the highest number of nodules per plant at 30 DAS was observed with B_1P_1 which recorded 34.43 which was significant over other treatments, while B_2P_1 recorded significantly the highest nodules at 60 DAS with 48.89 nodules per plant. The lowest number of nodules per plant was observed with B_0P_0 which recorded 30.80 and 26.22 at 30 DAS and 42.89 and 43.78 at 60 DAS during 2016 and 2017, respectively while in the pooled data it recorded 28.51 and 43.33 at 30 and 60 DAS, respectively. It was observed that application of boron along with seed treatment of phosphorus solubilizing biofertilizer have a significant effect on the number of nodules per plant.

Sentimenla *et al.* (2012) revealed that root nodulations in soybean significantly increased with application of phosphorus and boron. Chatterjee & Bandyopadhyay (2017) also observed that the number of nodules in cowpea was significantly increased by the interaction between foliar application of boron along with seed treatment with molybdenum and biofertilizers (*Rhizobium* + PSB).

4.1.3.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on the number of nodules per plant

The results on the overall interaction effect of sulphur, boron and phosphorus solubilizing biofertilizer on the number of nodules per plant have been presented on Table 4.1.3 (c). The results obtained from two years data revealed that at 30 DAS, $S_2B_1P_1$ recorded the highest nodules with 42.73 nodules per plant during 2016, while $S_2B_2P_1$ recorded the highest nodules with 38.00 nodules per plant during 2017. At 60 DAS, the highest number of nodules was obtained with treatment combination $S_2B_2P_1$ which recorded 52.00 and 51.67 nodules per plant during 2016 and 2017, respectively. As apparent from the pooled data, the highest number of nodules was obtained with treatment $S_2B_1P_1$ at 30 DAS with 38.87 nodules per plant while at 60 DAS $S_2B_2P_1$ recorded the highest number of nodules per plant (51.83). The lowest number of nodules per plant was observed with $S_0B_0P_0$ which recorded 26.00 and 40.67 nodules per plant at 30 and 60 DAS, respectively. At 30 DAS treatment $S_2B_1P_1$ was observed to be significant over

Table 4.1.3 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on number of nodules at different days after sowing

Treatments	Number of nodules plant^{-1}					
	30 DAS			60 DAS		
	2016	2017	Pooled	2016	2017	Pooled
$S_0B_0P_0$	27.67	24.33	26.00	40.00	41.33	40.67
$S_0B_0P_1$	30.20	25.33	27.77	43.33	45.33	44.33
$S_0B_1P_0$	30.53	26.33	28.43	43.67	46.33	45.00
$S_0B_1P_1$	36.33	27.67	32.00	43.33	47.33	45.33
$S_0B_2P_0$	28.50	25.33	26.92	44.33	43.33	43.83
$S_0B_2P_1$	24.93	30.33	27.63	47.33	46.00	46.67
$S_1B_0P_0$	32.07	26.00	29.03	45.33	44.33	44.83
$S_1B_0P_1$	24.53	31.33	27.93	47.33	45.67	46.50
$S_1B_1P_0$	31.70	25.67	28.68	43.33	44.33	43.83
$S_1B_1P_1$	32.83	32.00	32.42	45.33	46.67	46.00
$S_1B_2P_0$	31.20	30.00	30.60	45.00	43.00	44.00
$S_1B_2P_1$	35.37	33.67	34.52	49.00	47.33	48.17
$S_2B_0P_0$	32.67	28.33	30.50	43.33	45.67	44.50
$S_2B_0P_1$	39.80	31.67	35.73	47.33	48.33	47.83
$S_2B_1P_0$	33.43	30.67	32.05	47.33	46.00	46.67
$S_2B_1P_1$	42.73	35.00	38.87	47.67	48.33	48.00
$S_2B_2P_0$	30.67	31.00	30.83	47.00	46.67	46.83
$S_2B_2P_1$	28.87	38.00	33.43	52.00	51.67	51.83
SEm±	***1.65***	***0.54***	***0.87***	***0.33***	***0.51***	***0.30***
CD(P=0.05)	***4.90***	***1.62***	***2.49***	***0.99***	***1.51***	***0.87***

other treatment combinations, while towards later growth stage *i.e*., at 60 DAS $S_2B_2P_1$ was significant over all other treatment combinations.

The increased in the number of nodules per plant could be due to improved P availability in soil which enhanced symbiotic N_2 fixation through PSB (Gupta *et al*., 1998) and also due to the role of sulphur in nitrogenase enzyme activity responsible for root nodulation and nitrogen fixation in legumes (Najar *et al*., 2011), as a result of sulphur and phosphorus solubilizing biofertilizer application while boron nutrition enhanced *Rhizobium* activity in soybean (Chaithra & Hebsur, 2018).

4.1.4 Effect on number of branches per plant

4.1.4.1. Effect of sulphur on number of branches per plant

The effect of sulphur, boron and phosphorus solubilizing biofertilizer on the number of branches per plant at different stages of growth has been presented on Table 4.1.4 (a). As evident from the results obtained from the two years data, application of S_2 (40 kg S ha^{-1}) gives the highest number of branches per plant with 2.06 and 1.94 at 30 DAS, 5.96 and 5.79 at 60 DAS during 2016 and 2017, respectively. Whereas, the lowest number of branches was observed with S_0 (0 kg S ha^{-1}) which recorded 1.89 and 1.72 at 30 DAS, 5.22 and 5.03 at 60 DAS during 2016 and 2017, respectively. The pooled data of two years trial revealed that the highest number of branches was observed with S_2 both at 30 and 60 DAS with 2.00 and 5.88 branches per plant, respectively. It was observed that sulphur application did not have significant effect at 30 DAS. However, at 60 DAS sulphur application have significant effect on the number of branches per plant. Treatment S_2 was observed to be significant over S_0 and S_1 at 60 DAS.

Table 4.1.4 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on number of branches at different days after sowing

Treatments	Number of branches plant^{-1}					
	30 DAS			60 DAS		
	2016	2017	Pooled	2016	2017	Pooled
S_0	1.89	1.72	1.81	5.22	5.03	5.13
S_1	1.94	1.78	1.86	5.54	5.48	5.51
S_2	2.06	1.94	2.00	5.96	5.79	5.88
SEm±	***0.14***	***0.06***	***0.08***	***0.03***	***0.02***	***0.02***
CD(P=0.05)	***NS***	***NS***	***NS***	***0.14***	***0.08***	***0.06***
B_0	1.78	1.61	1.69	5.41	5.18	5.29
B_1	2.06	1.89	1.97	5.49	5.37	5.43
B_2	2.06	1.94	2.00	5.83	5.75	5.79
SEm±	***0.12***	***0.13***	***0.09***	***0.04***	***0.01***	***0.02***
CD(P=0.05)	***NS***	***NS***	***NS***	***0.12***	***0.03***	***0.06***
P_0	1.67	1.63	1.65	5.26	5.19	5.23
P_1	2.26	2.00	2.13	5.89	5.68	5.78
SEm±	***0.12***	***0.09***	***0.07***	***0.03***	***0.02***	***0.02***
CD(P=0.05)	***0.35***	***0.27***	***0.21***	***0.08***	***0.07***	***0.05***

The increased in the number of branches per plant could be attributed to the positive effect of sulphur nutrition on vegetative growth in soybean. Lakshman *et al.* (2015) concluded that application of 45 kg S ha^{-1} significantly increase the number of branches per plant in soybean. The findings of Choudhary *et al*. (2014) corroborated the results of this finding.

4.1.4.2. Effect of boron on number of branches per plant

The effects of boron application on the number of branches per plant have been presented on Table 4.1.4 (a). As evident from the results obtained from the two years data, the highest number of branches per plant was observed with B_1 and B_2 at 30 DAS which have the same value of 2.06 during 2016 whereas during 2017 B_2 recorded highest number of branches per plant with an average of 1.94. At 60 DAS, B_2 recorded the highest number of branches per plant with 5.83 and 5.75 during 2016 and 2017, respectively. The lowest was observed with B_0 with 1.78 and 1.61 branches per plant at 30 DAS, 5.22 and 5.03 branches per plant at 60 DAS during 2016 and 2017, respectively. As apparent from the pooled data of the two years results B_2 recorded the highest with 2.00 and 5.79 branches per plant while the lowest was observed with B_0 with 1.69 and 5.29 branches per plant both at 30 and 60 DAS, respectively. It was observed that application of boron did not have significant effect on number of branches per plant at 30 DAS. However, at 60 DAS application of boron did have a significant effect on the number of branches per plant which might be due to higher uptake of nutrients from the soil as a result of better root development with advancement of growth.

The increased in the number of branches per plant could be attributed to the functions of boron in cell differentiation development, translocation of photosynthates and growth regulators to different parts of the plant (Chaithra &

Hebsur, 2018). The results are in concurrence with the findings of Ravi *et al*. (2017) and Chaithra and Hebsur (2018).

4.1.4.3. Effect of phosphorus solubilizing biofertilizer on number of branches per plant

Table 4.1.4 (a) presents the results on the effect of phosphorus solubilizing biofertilizer on number of branches per plant. It was observed that seed treatment with phosphorus solubilizing biofertilizer, P_1 recorded higher number of branches with 2.26 and 2.00 at 30DAS, and 5.89 and 5.68 branches per plant at 60 DAS while P_0 recorded 1.67 and 1.63 at 30 DAS, 5.26 and 5.19 branches per plant at 60 DAS during 2016 and 2017, respectively. The pooled data revealed that P_1 recorded higher number of branches per plant as compared to non treated seeds with 2.13 and 5.78 branches per plant at 30 and 60 DAS, respectively. It is apparent from the results that seed treatment with phosphorus solubilizing biofertilizer P_1 had significant effect on the number of branches per plant.

Raja and Takankhar (2017) revealed that application PSB significantly increased the number of branches and opined that the increased in the number of branches could be ascribed to enhanced organic acid secretion and phosphatase enzyme activity by PSB which solubilizes P and improved its availability. The observations are in accordance with the findings of Khaswa *et al*. (2014), Pindkurwar *et al*. (2015) and Singh *et al*. (2010).

4.1.4.4. Effect of sulphur and boron interaction on the number of branches per plant

The interaction effect of sulphur and boron has been presented on Table 4.1.4 (b). It was observed that application of sulphur increases the number of branches however, when applied along with boron the increase in the number of branches was more pronounced. The highest number of branches per plant was observed with S_0B_2 with 2.33 at 30 DAS during 2016 while during 2017 S_2B_2 was highest with 2.17. At 60 DAS, the highest number of branches per plant was observed with S_2B_2 which recorded 6.47 and 6.28 during 2016 and 2017, respectively. The lowest was observed with S_0B_0 which recorded 1.50 and 1.50 at 30 DAS, 5.10 and 4.68 at 60 DAS during 2016 and 2017, respectively. The pooled data revealed that S_2B_2 gives the highest number of branches per plant with 2.17 and 6.38 while the lowest was observed with S_0B_0 with 1.50 and 4.89 at 30 and 60 DAS.

At 30 DAS the treatment combinations did not have any significant effect on the number of branches. However, at 60 DAS, the treatments have significant interaction effect and S_2B_2 was observed to be significant over other treatment combinations which could be due to better utilization of nutrients from the soils as a result of well established root system with advancement of growth.

The increased in number of branches per plant could be attributed to better plant nutrition through sulphur and boron application resulting in higher net photosynthates accumulation. Ravi *et al.* (2017) observed that application of 30 kg S ha^{-1} and 1 kg B ha^{-1} along with recommended dose of fertilizer and 12 kg $ZnSO_4$ recorded the highest number of branches per plant. Layek *et al*. (2014) also concluded that application of 30 kg S ha^{-1} and 1.5 kg B ha^{-1} recorded the highest number of branches per plant.

Table 4.1.4 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on number of branches at different days after sowing

Treatments	**Number of branches plant^{-1}**					
	30 DAS			**60 DAS**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0B_0	1.50	1.50	1.50	5.10	4.68	4.89
S_0B_1	1.83	1.83	1.83	5.28	5.22	5.25
S_0B_2	2.33	1.83	2.08	5.28	5.18	5.23
S_1B_0	2.00	1.50	1.75	5.40	5.33	5.37
S_1B_1	2.17	2.00	2.08	5.50	5.32	5.41
S_1B_2	1.67	1.83	1.75	5.73	5.78	5.76
S_2B_0	1.83	1.83	1.83	5.72	5.53	5.63
S_2B_1	2.17	1.83	2.00	5.70	5.57	5.63
S_2B_2	2.17	2.17	2.17	6.47	6.28	6.38
SEm±	***0.20***	***0.23***	***0.15***	***0.07***	***0.02***	***0.03***
CD(P=0.05)	***NS***	***NS***	***NS***	***0.20***	***0.05***	***0.10***
S_0P_0	1.67	1.56	1.61	4.96	4.89	4.92
S_0P_1	2.11	1.89	2.00	5.49	5.17	5.33
S_1P_0	1.67	1.56	1.61	5.26	5.28	5.27
S_1P_1	2.22	2.00	2.11	5.83	5.68	5.76
S_2P_0	1.67	1.78	1.72	5.58	5.40	5.49
S_2P_1	2.44	2.11	2.28	6.34	6.19	6.27
SEm±	***0.20***	***0.16***	***0.13***	***0.05***	***0.04***	***0.03***
CD(P=0.05)	***NS***	***NS***	***NS***	***0.14***	***0.11***	***0.09***
B_0P_0	1.56	1.44	1.50	5.17	4.97	5.07
B_0P_1	2.00	1.78	1.89	5.64	5.40	5.52
B_1P_0	1.67	1.67	1.67	5.24	5.16	5.20
B_1P_1	2.44	2.11	2.28	5.74	5.58	5.66
B_2P_0	1.78	1.78	1.78	5.38	5.44	5.41
B_2P_1	2.33	2.11	2.22	6.28	6.06	6.17
SEm±	***0.20***	***0.16***	***0.13***	***0.05***	***0.04***	***0.03***
CD(P=0.05)	***NS***	***NS***	***NS***	***0.14***	***0.11***	***0.09***

4.1.4.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on the number of branches per plant

The interaction effect of sulphur and phosphorus solubilizing biofertilizer has been presented in Table 4.1.4 (b). As evident from the results obtained from the two years data, increasing the level of sulphur increases the number of branches per plant. However, when sulphur was applied along with seed treatment with phosphorus solubilizing biofertilizer the increase in the number of branches per plant was more apparent. The maximum number of branches per plant was observed with treatment S_2P_1 with 2.44 and 2.11 at 30 DAS and 6.28 and 6.06 at 60 DAS during the year 2016 and 2017, respectively. The lowest number of branches per plant was observed with S_0P_0 (control) with an average number of branches per plant of 1.67 and 1.56 at 30 DAS and 4.96 and 4.89 at 45 DAS during 2016 and 2017, respectively. From the pooled data, it is evident that application of S_2P_1 recorded the maximum number of branches per plant with 2.28 and 6.27 at 30 and 60 DAS, respectively. It was observed that the different treatment combinations did not have any significant effect on the number of branches at 30 DAS. However, at 60 DAS the treatments have significant effect on the number of branches and treatment S_2P_1 was observed to be statistically significant over other treatments.

The increased in the number of branches might be due to better root development and nodulations which facilitates better nutrient utilization resulting in better growth in soybean (Suman *et al*., 2018). Nagar *et al*. (2018) also observed that application of sulphur up to 60 kg S ha^{-1} along with *Rhizobium* and PSB recorded significantly higher number of branches per plant in soybean.

4.1.4.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on the number of branches per plant

From Table 4.1.4 (b), it was apparent that application of B_1P_1 recorded the highest number of branches per plant with 2.44 at 30 DAS during 2016 while B_1P_1 and B_2P_1 recorded the maximum with the same value of 2.11 branches per plant during 2017. At 60 DAS, B_2P_1 recorded the maximum number of branches per plant with 6.28 and 6.06 during 2016 and 2017, respectively. The lowest number of branches per plant was observed with B_0P_0 (control) with 1.56 and 1.44 at 30 DAS during 2016 and 2017, respectively while at 60 DAS the lowest was observed with 5.17 during 2016 and B_1P_0 during 2017. The pooled data of two years observation revealed that the maximum number of branches per plant was observed with B_2P_1 with an average of 2.28 at 30 DAS while at 60 DAS B_2P_1 recorded maximum with a value of 6.17. The lowest number of branches per plant was observed with B_0P_0 (control) with a corresponding value of 1.50 and 5.07 at 30 and 60 DAS, respectively. It was observed that the treatment did not have significant effect on number of branches per plant at 30 DAS. However, towards the later stage of growth i.e., at 60 DAS the different treatment combinations shows significance where B_2P_1 was statistically significant over other treatment combinations.

The increased in the number of branches per plant might be due to improved plant nutrition which triggered better growth and development as a result of boron and phosphorus solubilizing biofertilizer application. Sentimenla *et al*. (2012) also opined that the growth attributes in soybean were significantly influenced by application of different levels of phosphorus and boron.

4.1.4.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on the number of branches per plant

The interaction effect of sulphur, boron and phosphorus solubilizing biofertilizer on the number of branches per plant has been presented on Table 4.1.4 (c). It was observed that at 30 DAS the number of branches was highest with $S_2B_1P_1$ and $S_2B_2P_1$ during 2016 both with 2.67 while during 2017 $S_1B_1P_1$ and $S_2B_2P_1$ recorded the highest both with 2.33 branches per plant on an average. Treatment combination $S_0B_0P_0$, $S_0B_1P_0$ and $S_1B_2P_0$ recorded the lowest where all three recorded 1.33 branches per plant during 2016 whereas treatment $S_0B_0P_0$ and $S_1B_0P_0$ recorded the lowest both with 1.33 branches per plant during 2017. It is evident from the results that the different treatment combinations did not have any significant effect on the number of branches at 30 DAS. At 60 DAS, the highest number of branches per plant was observed with treatment $S_2B_2P_1$ with 7.20 and 7.00 while the lowest was observed with $S_0B_0P_0$ (control) with 4.87 and 4.47 during 2016 and 2017, respectively. It was observed that treatment $S_2B_2P_1$ was significant over other treatment combinations.

The pooled data of the two years results revealed that treatment $S_2B_2P_1$ recorded the highest number of branches with 2.50 while $S_0B_0P_0$ recorded the lowest with 4.67 branches per plant. It was observed increased in the number of branches was more noticeable when sulphur and boron are apllied along with phosphorus solubilizing biofertilizer. There was no significance at 30 DAS, however, at 60 DAS the treatment has significant effect on the number of branches per plant.

The increased in the number of branches might be due to improved nutrient availability creating optimum condition for plant growth and development through application of sulphur, boron and phosphorus solubilizing biofertilizer.

Table 4.1.4 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on number of branches at different days after sowing

Treatments	Number of branches plant^{-1}					
	30 DAS			60 DAS		
	2016	2017	Pooled	2016	2017	Pooled
$S_0B_0P_0$	1.33	1.33	1.33	4.87	4.47	4.67
$S_0B_0P_1$	1.67	1.67	1.67	5.33	4.90	5.12
$S_0B_1P_0$	1.33	1.67	1.50	5.00	5.00	5.00
$S_0B_1P_1$	2.33	2.00	2.17	5.57	5.43	5.50
$S_0B_2P_0$	2.33	1.67	2.00	5.00	5.20	5.10
$S_0B_2P_1$	2.33	2.00	2.17	5.57	5.17	5.37
$S_1B_0P_0$	1.67	1.33	1.50	5.13	5.17	5.15
$S_1B_0P_1$	2.33	1.67	2.00	5.67	5.50	5.58
$S_1B_1P_0$	2.00	1.67	1.83	5.23	5.10	5.17
$S_1B_1P_1$	2.33	2.33	2.33	5.77	5.53	5.65
$S_1B_2P_0$	1.33	1.67	1.50	5.40	5.57	5.48
$S_1B_2P_1$	2.00	2.00	2.00	6.07	6.00	6.03
$S_2B_0P_0$	1.67	1.67	1.67	5.50	5.27	5.38
$S_2B_0P_1$	2.00	2.00	2.00	5.93	5.80	5.87
$S_2B_1P_0$	1.67	1.67	1.67	5.50	5.37	5.43
$S_2B_1P_1$	2.67	2.00	2.33	5.90	5.77	5.83
$S_2B_2P_0$	1.67	2.00	1.83	5.73	5.57	5.65
$S_2B_2P_1$	2.67	2.33	2.50	7.20	7.00	7.10
SEm±	***0.35***	***0.27***	***0.22***	***0.08***	***0.07***	***0.05***
CD(P=0.05)	***NS***	***NS***	***NS***	***0.23***	***0.20***	***0.15***

Layek *et al*. (2014) also concluded that application of 30 kg S ha^{-1} and 1.5 kg B ha^{-1} recorded the highest number of branches per plant. Nagar *et al*. (2018) also observed that application of sulphur up to 60 kg S ha^{-1} along with *Rhizobium* and PSB recorded significantly higher number of branches per plant in soybean. Sentimenla *et al*. (2012) also opined that the growth attributes in soybean were significantly influenced by application of different levels of phosphorus and boron.

4.1.5 Effect on plant dry matter

4.1.5.1. Effect of sulphur on plant dry matter

As evident from the results presented in Table 4.1.5 (a), application of sulphur increased the dry matter accumulation at different stages of plant growth. It was observed that application of S_2 (40 kg S ha^{-1}) recorded the highest plant dry matter accumulation with 27.47 and 27.38 g $plant^{-1}$ at 60 DAS and 38.34 and 38.53 g $plant^{-1}$ at 90 DAS during 2016 and 2017, respectively. The lowest was observed with S_0 (control) which recorded 25.51 and 25.62 g $plant^{-1}$ at 60 DAS and 35.13 and 34.95 g $plant^{-1}$ at 90 DAS during 2016 and 2017, respectively. The pooled data of the two years results revealed that application of S_2 recorded the highest plant dry matter accumulation with an average of 27.42 and 38.53 g $plant^{-1}$ while S_0 recorded the lowest with an average of 25.57 and 35.04 g $plant^{-1}$ at 60 and 90 DAS, respectively. It was observed that treatment S_2 was significant over treatment S_1 and S_0. In general, increasing the levels of sulphur application increased the plant dry matter accumulation at different stages of plant growth.

The increased in the plant dry matter could be attributed to improved root nodulation and biological nitrogen fixation through enhanced nitrogenase enzyme activity as influenced by sulphur resulting in better vegetative growth and dry

Table 4.1.5 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on plant dry matter at different days after sowing

Treatments	**Plant dry matter (g plant^{-1})**					
	60 DAS			**90 DAS**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	25.51	25.62	25.57	35.13	34.95	35.04
S_1	26.63	26.46	26.55	36.84	36.85	36.85
S_2	27.47	27.38	27.42	38.34	38.73	38.53
SEm±	***0.16***	***0.08***	***0.09***	***0.02***	***0.05***	***0.03***
CD(P=0.05)	***0.63***	***0.30***	***0.29***	***0.10***	***0.21***	***0.10***
B_0	25.57	25.86	25.71	35.98	36.32	36.15
B_1	26.42	26.31	26.37	36.81	36.53	36.67
B_2	27.62	27.29	27.45	37.51	37.69	37.60
SEm±	***0.15***	***0.11***	***0.09***	***0.02***	***0.06***	***0.03***
CD(P=0.05)	***0.45***	***0.33***	***0.26***	***0.06***	***0.20***	***0.10***
P_0	26.14	25.83	25.98	36.50	36.63	36.56
P_1	26.94	27.14	27.04	37.04	37.06	37.05
SEm±	***0.11***	***0.06***	***0.06***	***0.02***	***0.05***	***0.03***
CD(P=0.05)	***0.34***	***0.18***	***0.18***	***0.05***	***0.14***	***0.07***

matter accumulation (Najar *et* al., 2011). Modhavadiya *et al*. (2018) concluded that significantly higher dry matter yield per plant were obtained with application of 30 kg S ha^{-1} in sesamum. Similar findings on plant dry matter in soybean at harvest were also reported by Layek *et al*. (2014) and Vitso (2014).

4.1.5.2. Effect of boron on plant dry matter

The effect of boron on plant dry matter accumulation has been presented on Table 4.1.5 (a). It was observed that application of B_2 recorded the highest plant dry matter accumulation with 27.62 and 27.29 g $plant^{-1}$ at 60 DAS and 37.51 and 37.69 g $plant^{-1}$ at 90 DAS during 2016 and 2017, respectively. The lowest plant dry matter accumulation at different stages of growth was observed with B_0 (control) which recorded 25.57 and 25.86 g $plant^{-1}$ at 60 DAS and 35.98 and 36.32 g $plant^{-1}$ during 2016 and 2017, respectively. As apparent from the pooled data, the average dry matter accumulation was highest with application of B_2 which recorded 27.45 and 37.60 g $plant^{-1}$ whereas, the lowest was observed with B_0 having 25.71 and 36.15 g $plant^{-1}$ at 60 and 90 DAS, respectively. Application of boron was observed to have a significant effect on plant dry matter accumulation. Treatment B_2 was found to be significant over treatment B_1 and B_0.

The increased in plant dry matter might be due to boron which played a vital role in cell differentiation leading to improved growth and dry matter accumulation. Modhavadiya *et al*. (2018) reported that significantly the highest dry matter yield per plant in sesamum was recorded with application of 3 kg B ha^{-1} which was statistically at par with 2 kg B ha^{-1}. Similar finding was also reported by Layek *et al*. (2014) with application of 1.5 kg B ha^{-1} in soybean.

4.1.5.3. Effect of phosphorus solubilizing biofertilizer on plant dry matter

The effect of phosphorus solubilizing biofertilizer on plant dry matter accumulation has been presented in Table 4.1.5 (a). It was observed that application of phosphorus solubilizing biofertilizer as seed treatment accumulated higher plant dry matter which recorded 26.94 and 27.14 g plant^{-1} at 60 DAS and 37.04 and 37.06 g plant^{-1} at 90 DAS as compared to non treated seeds *i.e.*, control which recorded 26.14 and 25.83 g plant^{-1} at 60 DAS and 36.50 and 36.63 g plant^{-1} at 90 DAS during 2016 and 2017, respectively. It is clear from the pooled data that P_1 recorded higher plant dry matter accumulation with an average of 27.04 and 37.05 g plant^{-1} as compared to P_0 which recorded 25.98 and 36.56 g plant^{-1} at 60 and 90 DAS, respectively. It has been found application of phosphorus solubilizing biofertilizer have a significant influence on plant dry matter accumulation. Treatment P_1 was found to be significant over P_0.

The increased in plant dry matter accumulation might be due to solubilization of phosphate present in the soil by phosphorus solubilizing biofertilizer application which increases its availability for plant uptake resulting better root system and nodulation and improved plant growth. Nagar *et al.* (2018), Pindkurwar *et al.* (2015) and Raja & Takankhar (2017) also reported that seed treatment with PSB significantly increased plant dry matter accumulation in soybean.

4.1.5.4. Effect of sulphur and boron interaction on plant dry matter

The interaction effect between sulphur and boron has been presented on Table 4.1.5 (b). It was observed that the interaction between S_2B_2 recorded the highest plant dry matter accumulation with 29.07 and 28.67 g plant^{-1} at 60 DAS and 39.08 and 39.51 g plant^{-1} at 90 DAS during the year 2016 and 2017,

Table 4.1.5 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on plant dry matter at different days after sowing

Treatments	Plant dry matter (g plant^{-1})					
	60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled
S_0B_0	24.71	25.21	24.96	34.34	34.38	34.36
S_0B_1	25.82	25.54	25.68	35.07	34.86	34.97
S_0B_2	25.99	26.12	26.06	35.97	35.62	35.79
S_1B_0	25.76	25.86	25.81	36.01	36.22	36.11
S_1B_1	26.35	26.44	26.39	37.01	36.41	36.71
S_1B_2	27.79	27.09	27.44	37.49	37.94	37.72
S_2B_0	26.24	26.49	26.37	37.59	38.37	37.98
S_2B_1	27.10	26.97	27.03	38.36	38.31	38.33
S_2B_2	29.07	28.67	28.87	39.08	39.51	39.29
SEm±	***0.25***	***0.18***	***0.16***	***0.04***	***0.11***	***0.06***
CD(P=0.05)	***0.79***	***0.57***	***0.46***	***0.11***	***0.35***	***0.17***
S_0P_0	25.23	25.27	25.25	34.90	34.75	34.83
S_0P_1	25.79	25.97	25.88	35.35	35.16	35.25
S_1P_0	26.22	25.66	25.94	36.56	36.77	36.67
S_1P_1	27.05	27.26	27.16	37.11	36.94	37.02
S_2P_0	26.96	26.57	26.76	38.03	38.36	38.20
S_2P_1	27.98	28.19	28.08	38.65	39.10	38.87
SEm±	***0.20***	***0.10***	***0.11***	***0.03***	***0.08***	***0.04***
CD(P=0.05)	***NS***	***0.31***	***0.32***	***0.09***	***0.24***	***0.12***
B_0P_0	24.96	25.24	25.10	35.61	36.35	35.98
B_0P_1	26.19	26.48	26.33	36.35	36.29	36.32
B_1P_0	26.16	25.72	25.94	36.66	36.15	36.41
B_1P_1	26.69	26.91	26.80	36.96	36.90	36.93
B_2P_0	27.29	26.55	26.92	37.22	37.37	37.30
B_2P_1	27.94	28.04	27.99	37.80	38.01	37.90
SEm±	***0.20***	***0.10***	***0.11***	***0.03***	***0.08***	***0.04***
CD(P=0.05)	***NS***	***NS***	***NS***	***0.09***	***0.24***	***0.12***

respectively. The lowest plant dry matter accumulation was recorded with S_0B_0 (control) with 24.71 and 25.21 g plant^{-1} at 60 DAS and 34.34 and 34.38 g plant^{-1} at 90 DAS during 2016 and 2017, respectively. The pooled data revealed that interaction between S_2B_2 recorded the highest plant dry matter with an average of 28.87 and 39.29 g plant^{-1} while the lowest was recorded with S_0B_0 with 24.96 and 34.36 g plant^{-1} at 60 and 90 DAS, respectively. The results obtained from the two years observations revealed that increasing the level of boron application increased the plant dry matter accumulation at all levels of sulphur. Treatment S_2B_2 was found to be significant over all other treatment combinations.

The increased in plant dry matter might be ascribed to the positive effect of S and B on the growth attributes resulting in higher dry matter accumulation. Layek *et al*. (2014) revealed that the highest dry matter accumulation in soybean was recorded with combined application of 30 kg S ha^{-1} and 1.0 kg B ha^{-1}.

4.1.5.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on plant dry matter

The results on interaction effect between sulphur and phosphorus solubilizing biofertilizer interaction on plant dry matter has been presented on Table 4.1.5 (b). As apparent from the results, application of 40 kg S ha^{-1} (S_2) along with seed treatment with phosphorus solubilizing biofertilizer (P_1) *i.e.*, treatment S_2P_1 recorded the highest plant dry matter accumulation with 27.98 and 28.19 g plant^{-1} at 60 DAS and 38.65 and 39.10 g plant^{-1} at 90 DAS during 2016 and 2017, respectively. The lowest plant dry matter accumulation was observed with S_0P_0 (control) with corresponding value of 25.23 and 25.25 g plant^{-1} at 60 DAS and 34.90 and 34.75 g plant^{-1} at 90 DAS during 2016 and 2017, respectively. The pooled data of the two years observations revealed that S_2P_1 recorded the highest plant dry matter with an average of 28.08 and 38.87 g plant^{-1} while S_0P_0 was the lowest with 25.25 and 34.83 g plant^{-1} at 60 and 90 DAS, respectively. Treatment combination S_2P_1 was found to be significantly better than other treatment combinations. It was observed that increased level of sulphur application up to 40 kg S ha^{-1} (S_2) along with seed treatment with phosphorus solubilizing biofertilizer (P_1) had a significant influence on plant dry matter accumulation than application of sulphur alone.

The reason for increased plant dry matter accumulation could be attributed to improved nutrient availability creating an ideal condition for plant growth through higher P solubilization by phosphorus solubilizing biofertilizer and sulphur nutrition. Nagar *et al*. (2018) opined that application of 40 kg S ha^{-1} and seeed inoculation with *Rhizobium* + PSB recorded higher plant dry matter in soybean.

4.1.5.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on plant dry matter

Table 4.1.5 (b) presented the effect of boron and phosphorus solubilizing biofertilizer interaction on plant dry matter. The highest plant dry matter accumulation was observed with application of B_2P_1 having 27.94 and 28.04 g plant^{-1} at 60 DAS and 37.80 and 38.01 g plant^{-1} at 90 DAS during 2016 and 2017, respectively. The control treatment *i.e.*, B_0P_0 recorded the lowest plant dry matter with 24.96 and 25.24 g plant^{-1} at 60 DAS and 35.61 and 36.35 g plant^{-1} at 90 DAS during 2016 and 2017, respectively. The pooled data obtained from the two years results revealed that B_2P_1 recorded highest plant dry matter with an average of 27.99 and 37.90 g plant^{-1} while B_0P_0 was the lowest with 24.96 and 35.98 g plant^{-1} at 60 and 90 DAS, respectively. There was no significant effect of the treatment on plant dry matter accumulation at 30 DAS. However, at 90 DAS application of increased levels of boron along with seed treatment with phosphorus solubilizing biofertilizer had a significant influence on plant dry matter aculmulation. Treatment B_2P_1 was found to be significant over all other treatment combinations at 90 DAS.

The improved plant nutrition through application of boron and phosphorus solubilizing biofertilizer might be responsible for increased plant dry matter accumulation. Similar results on plant dry matter accumulation in soybean have been reported by Layek *et al*. (2014) and Vitso (2014).

4.1.5.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on plant dry matter

In Table 4.1.5 (c) the overall interaction effect of sulphur, boron and phosphorus solubilizing biofertilizer on plant dry matter has been presented. The lowest plant dry matter accumulation was observed with the control treatment ($S_0B_0P_0$) with corresponding value of 24.52 and 24.92 at 60 DAS and 34.00 and 34.26 at 90 DAS whereas the highest was observed with $S_2B_2P_1$ having 29.45 and 29.32 at 60 DAS and 39.46 and 39.92 at 90 DAS during 2016 and 2017, respectively. From the pooled data, it was apparent that $S_2B_2P_1$ gives the highest plant dry matter with an average of 29.32 and 39.69 while the lowest was $S_0B_0P_0$ (control) with 24.72 and 34.13 at 60 and 90 DAS, respectively. The interaction between the three factors *i.e.*, sulphur, boron and phosphorus solubilizing biofertilizer had a significant influence on plant dry matter accumulation at different stages of plant growth. Treatment $S_2B_2P_1$ was found to be statistically significant over all other treatment combinations including control.

The role of sulphur in improving root nodulation and biological nitrogen fixation by enhancing nitrogenase enzyme activity (Najar *et* al., 2011), role of boron in cell differentiation (Devi *et al*., 2012) and higher P solubilization

Table 4.1.5 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on plant dry matter at different days after sowing

Treatments	**Plant dry matter (g plant^{-1})**					
	60 DAS			**90 DAS**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
$S_0B_0P_0$	24.52	24.92	24.72	34.00	34.26	34.13
$S_0B_0P_1$	24.91	25.51	25.21	34.68	34.49	34.59
$S_0B_1P_0$	25.31	25.36	25.34	34.95	34.72	34.84
$S_0B_1P_1$	26.33	25.71	26.02	35.19	35.00	35.10
$S_0B_2P_0$	25.87	25.54	25.70	35.76	35.25	35.51
$S_0B_2P_1$	26.12	26.70	26.41	36.17	35.98	36.08
$S_1B_0P_0$	25.75	25.28	25.52	35.58	36.61	36.10
$S_1B_0P_1$	25.77	26.44	26.11	36.44	35.83	36.13
$S_1B_1P_0$	25.58	25.61	25.60	36.89	35.95	36.42
$S_1B_1P_1$	27.12	27.26	27.19	37.12	36.87	37.00
$S_1B_2P_0$	27.33	26.09	26.71	37.22	37.76	37.49
$S_1B_2P_1$	28.25	28.09	28.17	37.77	38.12	37.94
$S_2B_0P_0$	24.60	25.51	25.05	37.25	38.19	37.72
$S_2B_0P_1$	27.88	27.48	27.68	37.92	38.54	38.23
$S_2B_1P_0$	27.58	26.18	26.88	38.15	37.79	37.97
$S_2B_1P_1$	26.61	27.76	27.19	38.56	38.83	38.70
$S_2B_2P_0$	28.68	28.01	28.35	38.70	39.10	38.90
$S_2B_2P_1$	29.45	29.32	29.39	39.46	39.92	39.69
SEm±	***0.34***	***0.18***	***0.19***	***0.05***	***0.14***	***0.08***
CD(P=0.05)	***1.02***	***0.53***	***0.55***	***0.15***	***0.42***	***0.22***

by phosphorus solubilizing biofertilizer might be responsible for the increased dry matter accumulation. Layek *et al*. (2014) revealed that the highest dry matter accumulation in soybean was recorded with combined application of 30 kg S ha^{-1} and 1.0 kg B ha^{-1}. Nagar *et al*. (2018) opined that application of 40 kg S ha^{-1} and seed inoculation with *Rhizobium* + PSB recorded higher plant dry matter in soybean. Similar results on plant dry matter accumulation in soybean have been reported by Layek *et al*. (2014) and Vitso (2014).

4.2 Effect on yield attributes of soybean

The effect of sulphur, boron and phosphorus solubilizing biofertilizer on yield attributes of soybean *viz.* number of pods per plant, number of filled pods per plant, number of seed per pod and seed test weight are presented under the following headings:

4.2.1 Effect on number of pods per plant

4.2.1.1. Effect of sulphur on number of pods per plant

The effect of sulphur on the number of pods per plant has been given in Table 4.2 (a) and Fig. 4. As evident from the results, increased levels of sulphur application had a significant influence on the number of pods per plant. It was observed that application of 40 kg S ha^{-1} *i.e.*, S_2 gives the highest number of pods per plant with 95.65 and 95.82 while the lowest was recorded with S_0 (control) with 75.32 and 74.44 during 2016 and 2017, respectively. The pooled data revealed that S_2 recorded the highest number of pods per plant with an average of 95.74 while S_0 recorded the lowest with an average mean of 74.88. Treatment S_2 (40 kg S ha^{-1}) was found to be significant over S_1 (20 kg S ha^{-1}) and S_0 (0 kg S ha^{-1}) while S_1 was significant over S_0.

The increased number of pods per plant with increasing dose of sulphur might be due to the fact that many metabolic and enzymatic processes dictated by sulphur (Najar *et al*., 2011). Choudhary *et al*. (2014), Jamal *et al*. (2005) and Lakshman *et al*. (2015) suggested that the number of pods per plant in soybean was significantly increased with sulphur fertilization.

4.2.1.2. Effect of boron on number of pods per plant

Table 4.2(a) and Fig. 4 showed the effect of boron application on the number of pods per plant. It was observed that in general there was increase in the number of pods per plant with increased levels of boron application. The maximum number of pods per plant was recorded with application B_2 (2 kg B ha^{-1}) with an average of 88.98 and 89.11 while the minimum number of pods per plant was observed with B_0 (control) having 82.87 and 82.32 during 2016 and 2017, respectively. The pooled data of the two years observation shows that maximum number of pods per plant was observed B_2 (2 kg B ha^{-1}) having 89.04 while B_0 (control) gives the lowest with 82.32 on an average. Treatment B_2 was found to be significant over B_1 and B_0 while B_1 was significant over B_0.

Chaithra and Hebsur (2018) reported that boron regulates many metabolic activities and also pollination which greatly influenced the yield attributing parameters. This might be the reason for the increased number of pods per plant with boron fertilization. Chatterjee & Bandyopadhyay (2017) and Chaitra & Hebsur (2018) also opined that application of boron in soybean significantly increased the number of pods per plant.

Table 4.2 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on number of pods, number of filled pods, number of seed and seed test weight

Treatments	**Number of pods plant^{-1}**			**Number of filled pods plant^{-1}**			**Number of seed pod^{-1}**			**Seed test weight (g)**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	75.32	74.44	74.88	69.10	66.55	67.82	2.42	2.40	2.41	11.88	11.91	11.90
S_1	87.29	86.48	86.89	80.76	79.19	79.97	2.55	2.54	2.54	12.70	13.19	12.94
S_2	95.65	95.82	95.74	90.03	89.86	89.94	2.56	2.56	2.56	13.35	13.51	13.43
SEm±	***0.07***	***0.04***	***0.04***	***0.07***	***0.10***	***0.06***	***0.02***	***0.01***	***0.01***	***0.08***	***0.04***	***0.05***
CD(P=0.05)	***0.26***	***0.17***	***0.13***	***0.27***	***0.39***	***0.20***	***0.06***	***0.04***	***0.03***	***0.32***	***0.17***	***0.15***
B_0	82.87	82.32	82.60	75.95	74.67	75.31	2.47	2.47	2.47	12.34	12.49	12.42
B_1	86.42	85.31	85.86	80.08	78.54	79.31	2.51	2.50	2.50	12.69	12.87	12.78
B_2	88.98	89.11	89.04	83.86	82.39	83.12	2.55	2.54	2.54	12.90	13.25	13.08
SEm±	***0.04***	***0.03***	***0.03***	***0.06***	***0.16***	***0.09***	***0.02***	***0.02***	***0.01***	***0.04***	***0.06***	***0.04***
CD(P=0.05)	***0.14***	***0.09***	***0.08***	***0.18***	***0.51***	***0.26***	***0.07***	***0.05***	***0.04***	***0.13***	***0.19***	***0.11***
P_0	85.52	84.99	85.25	79.21	77.52	78.36	2.50	2.48	2.49	12.55	12.78	12.67
P_1	86.66	86.18	86.42	80.71	79.55	80.13	2.52	2.51	2.52	12.74	12.96	12.85
SEm±	***0.04***	***0.01***	***0.02***	***0.05***	***0.11***	***0.06***	***0.02***	***0.01***	***0.01***	***0.05***	***0.05***	***0.03***
CD(P=0.05)	***0.13***	***0.04***	***0.07***	***0.16***	***0.33***	***0.18***	***NS***	***NS***	***NS***	***0.15***	***0.13***	***0.10***

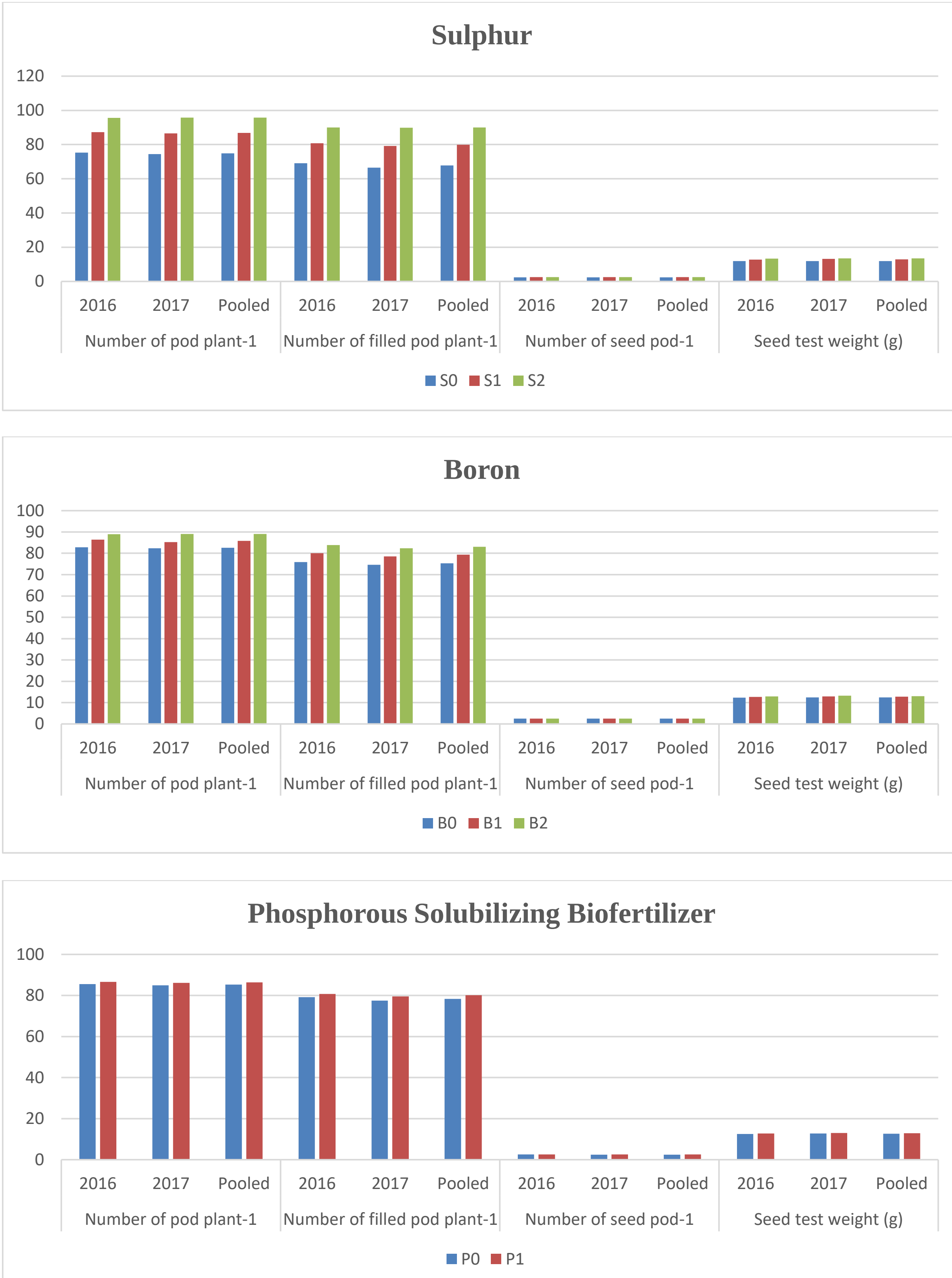


Fig. 4: Effect of sulfur, boron and phosphorus solubilizing biofertilizeron number of pods, number of filled pods, number of seed per plant and seed test weight

4.2.1.3. Effect of phosphorus solubilizing biofertilzer on number of pods per plant

The effect of phosphorus solubilizing biofertilizer on the number of pods per plant has been presented on Table 4.2(a) and Fig. 4. From the table it is apparent that application of phosphorus solubilizing biofertilizer as seed treatment had a significant influence on the number of pods per plant in soybean. Application P_1 recorded maximum number of pods per plant having 86.66 and 86.18 while the least number of pods per plant was observed with P_0 having 85.52 and 84.99 during 2016 and 2017, respectively. From the pooled data, it has been revealed that treatment P_1 recorded higher number of pods having 86.42 as compared to P_0 (control) which recorded 85.25 pods per plant on an average.

Gyaneshwar *et al*. (1998) reported that improved P solubilization through phosphate solubilizing micro-organisms promotes biological N_2 fixation and production of plant growth regulators. This might be responsible for the increased number of pods per plant in soybean with seed inoculation with phosphorus solubilizing biofertilizer. The increased in the number of pods per plant with application of PSB have also been reported by Devi *et al*. (2012), Devi *et al*. (2013), Pindkurwar *et al*. (2015) and Diep *et al*. (2016).

4.2.1.4. Effect of sulphur and boron interaction on number of pods per plant

Table 4.2 (b) shows the interaction effect between sulphur and boron on the number of pod per plant of soybean. It was observed that increased level of sulphur application increases the number of pods per plant but when sulphur was applied along with boron the increased was found to be more apparent. Increasing to the levels of boron application had a significant influence on the number of pods per plant at all levels of sulphur application. The highest number of pods per plant

Table 4.2 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on number of pods, number of filled pods, number of seed and seed test weight

Treatments	Number of pods plant^{-1}			Number of filled pods plant^{-1}			Number of seed pod^{-1}			Seed test weight (g)		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0B_0	70.66	70.13	70.40	63.80	61.46	62.63	2.35	2.34	2.34	11.37	11.43	11.40
S_0B_1	75.45	74.52	74.98	69.33	66.53	67.93	2.42	2.39	2.41	11.99	11.74	11.86
S_0B_2	79.87	78.66	79.26	74.16	71.66	72.91	2.49	2.48	2.48	12.29	12.56	12.42
S_1B_0	85.32	83.73	84.52	77.11	75.94	76.52	2.54	2.52	2.53	12.49	12.73	12.61
S_1B_1	87.82	85.98	86.90	81.00	79.35	80.18	2.55	2.55	2.55	12.74	13.33	13.04
S_1B_2	88.73	89.74	89.24	84.18	82.27	83.22	2.55	2.53	2.54	12.86	13.50	13.18
S_2B_0	92.64	93.10	92.87	86.95	86.59	86.77	2.51	2.53	2.52	13.18	13.32	13.25
S_2B_1	95.98	95.43	95.71	89.90	89.76	89.83	2.55	2.54	2.55	13.32	13.55	13.44
S_2B_2	98.33	98.93	98.63	93.25	93.23	93.24	2.63	2.60	2.61	13.57	13.68	13.62
SEm±	***0.08***	***0.05***	***0.05***	***0.10***	***0.29***	***0.15***	***0.04***	***0.03***	***0.02***	***0.08***	***0.11***	***0.07***
CD(P=0.05)	***0.24***	***0.15***	***0.13***	***0.31***	***0.88***	***0.44***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
S_0P_0	74.54	73.83	74.18	68.21	65.06	66.64	2.41	2.39	2.40	11.77	11.78	11.78
S_0P_1	76.11	75.05	75.58	69.98	68.04	69.01	2.43	2.41	2.42	11.99	12.04	12.01
S_1P_0	86.99	85.93	86.46	80.14	78.45	79.29	2.54	2.53	2.53	12.60	13.17	12.89
S_1P_1	87.59	87.04	87.31	81.38	79.92	80.65	2.55	2.54	2.55	12.79	13.21	13.00
S_2P_0	95.02	95.20	95.11	89.27	89.05	89.16	2.54	2.53	2.53	13.28	13.40	13.34
S_2P_1	96.28	96.44	96.36	90.78	90.67	90.73	2.58	2.58	2.58	13.43	13.63	13.53
SEm±	***0.08***	***0.02***	***0.04***	***0.09***	***0.19***	***0.11***	***0.03***	***0.02***	***0.02***	***0.09***	***0.08***	***0.06***
CD(P=0.05)	***0.23***	***0.07***	***0.11***	***0.27***	***0.58***	***0.31***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
B_0P_0	82.39	81.74	82.07	75.08	73.86	74.47	2.46	2.45	2.46	12.32	12.50	12.41
B_0P_1	83.35	82.90	83.12	76.82	75.47	76.15	2.47	2.47	2.47	12.37	12.49	12.43
B_1P_0	85.86	84.63	85.25	79.43	77.24	78.34	2.50	2.49	2.49	12.50	12.68	12.59
B_1P_1	86.97	85.99	86.48	80.72	79.85	80.29	2.52	2.50	2.51	12.87	13.06	12.96
B_2P_0	88.29	88.58	88.44	83.12	81.46	82.29	2.53	2.51	2.52	12.83	13.17	13.00
B_2P_1	89.66	89.64	89.65	84.60	83.31	83.96	2.58	2.56	2.57	12.98	13.33	13.15
SEm±	***0.08***	***0.02***	***0.04***	***0.09***	***0.19***	***0.11***	***0.03***	***0.02***	***0.02***	***0.09***	***0.08***	***0.06***
CD(P=0.05)	***0.23***	***0.07***	***0.11***	***0.27***	***0.58***	***0.31***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***

was observed with S_2B_2 having 98.33 and 98.93 while S_0B_0 gives the lowest with 70.66 and 70.66 during 2016 and 2017, respectively. The pooled data revealed that S_2B_2 recorded the maximum number of pods per plant with a value of 98.63 while S_0B_0 was the lowest with 70.40. As apparent from the data, there was significant difference between the different treatment and S_2B_2 was found to be significant over other treatment combinations.

The increased in the number of pods per plant might be due to the improved growth attributes through optimum plant nutrition which further got translated in yield characteristics like number of pods per plant (Ram *et al*., 2014). Similar findings on interaction effect of sulphur and boron on the number of pods per plant have been reported by Layek *et al*. (2014), Longkumer *et al*. (2017) and Ravi *et al*. (2017).

4.2.1.5. Effect of sulphur and phosphorus solubilizing biofertilzer interaction on number of pods per plant

The interaction effect between sulphur and phosphorus solubilizing biofertilzer interaction on number of pods per plant has been depicted on Table 4.2 (b). As evident from the table, increasing the levels of sulphur up to 40 kg S ha^{-1} increased the number of pods per plant. However, when sulphur was applied along with phosphorus solubilizing biofertilzer as seed treatment, there was significant increase in the number of pods per plant. Treatment combination S_2P_1 was found to have the highest number of pods per plant having 96.28 and 96.44 while S_0P_0 was the lowest with 74.54 and 73.83 during 2016 and 2017, respectively. The pooled data showed that S_2P_1 recorded the highest number of pods per plant having 96.36 and S_0P_0 was the lowest with 74.18 on an average. There was significant difference between the different treatment combinations and S_2P_1 was found to be significantly superior to other treatment combinations.

The application of phosphorus solubilizing biofertilizer solubilizes the insoluble phosphate to soluble form and increased its availability for plant uptake. The improved growth and yield characteristics like number of pods per plant with application of sulphur and phosphorus solubilizing biofertilizer could be attributed to efficient utilization of plant nutrients from the soils through their well established root system and nodulations (Suman *et al*., 2018). Synergistic interaction effect of phosphorus and sulphur on number of pods per plant had also been documented by Akter *et al*. (2013) and Yadav *et al*. (2013). Similar finding on the number of pods per plant as influenced by the interaction between sulphur and phosphorus has been reported by Majumdar *et al*. (2001).

4.2.1.6. Effect of boron and phosphorus solubilizing biofertilzer interaction on number of pods per plant

Table 4.2 (b) presented the effect of boron and phosphorus solubilizing biofertilizer interaction on number of pods per plant. The results obtained from the two years data revealed that the number of pods per plant increase with increased level of boron application. However, when boron was applied along with phosphorus solubilizing biofertilizer as seed treatment the increase in the number of pod per plant was more apparent. The maximum number of pods per plant was observed with treatment B_2P_1 having 89.66 and 89.64 while B_0P_0 recorded the lowest with 82.39 and 81.74 pods per plant during 2016 and 2017, respectively. The pooled data of the two years data revealed that plants receiving treatment B_2P_1 gives the highest number of pods per plant having 89.65 while B_0P_0 was the lowest with an average mean of 82.07. The different treatment combinations showed significant difference on the number of pods per plant. However, treatment B_2P_1 was found to be superior to other treatments.

Sentimenla *et al*. (2012) revealed that combined application of phosphorus and boron have significant interaction effect on the number of pods per plant in soybean. The application of phosphorus solubilizing biofertilizer as seed treatment might have increased P solubilization in soil which enhanced root development and nodulation in soybean. The improved nutrient uptake and growth through increased root nodulation and nitrogenase enzyme activity might be responsible for the increased number of pods per plant (Srivastava *et al*., 1998).

4.2.1.7. Effect of sulphur, boron and phosphorus solubilizing biofertilzer interaction on number of pods per plant

The interaction effect of sulphur, boron and phosphorus solubilizing biofertilzer on number of pod per plant of soybean has been presented in Table 4.2 (c). It was observed that plots receiving treatment combination $S_2B_2P_1$ recorded the highest number of pods per plant with corresponding value of 98.70 and 99.30 while the lowest was recorded with the control treatment $S_0B_0P_0$ which recorded 70.10 and 69.73 during 2016 and 2017, respectively. From the pooled data it has become evident that $S_2B_2P_1$ showed the highest number of pods per plant with an average mean of 99.00 whereas $S_0B_0P_0$ was the lowest with 69.92 pods per plant on an average. Significant difference was observed among the different treatment combinations, however treatment combination $S_2B_2P_1$ was found to be significant over all other treatment combinations.

Najar *et al*. (2011) suggested that many metabolic and enzymatic processes are dictated by sulphur. Chaithra and Hebsur (2018) also reported that boron regulates many metabolic activities and also pollination which greatly influenced the yield attributing parameters. Gyaneshwar *et al*. (1998) opined that improved P solubilization through phosphate solubilizing micro-organisms promotes biological N_2 fixation and production of plant growth regulators. Thus, increased

Table 4.2 (c) Interaction effects of sulfur, boron and phosphorus solubilizing biofertilizer on number of pods, number of filled pods, number of seed and seed test weight

Treatments	Number of pods plant^{-1}			Number of filled pods plant^{-1}			Number of seed pod^{-1}			Seed test weight (g)		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
$S_0B_0P_0$	70.10	69.73	69.92	62.79	60.46	61.63	2.35	2.33	2.34	11.36	11.50	11.43
$S_0B_0P_1$	71.22	70.53	70.87	64.80	62.47	63.63	2.36	2.34	2.35	11.38	11.36	11.37
$S_0B_1P_0$	74.89	73.53	74.21	68.40	64.12	66.26	2.42	2.39	2.41	11.73	11.41	11.57
$S_0B_1P_1$	76.00	75.51	75.76	70.27	68.93	69.60	2.42	2.40	2.41	12.25	12.06	12.16
$S_0B_2P_0$	78.63	78.22	78.43	73.45	70.60	72.02	2.45	2.46	2.46	12.23	12.44	12.33
$S_0B_2P_1$	81.10	79.10	80.10	74.87	72.72	73.80	2.52	2.50	2.51	12.35	12.69	12.52
$S_1B_0P_0$	84.97	83.12	84.05	76.13	75.49	75.81	2.55	2.53	2.54	12.44	12.84	12.64
$S_1B_0P_1$	85.67	84.33	85.00	78.08	76.40	77.24	2.52	2.52	2.52	12.54	12.62	12.58
$S_1B_1P_0$	87.70	85.70	86.70	80.73	78.75	79.74	2.54	2.56	2.55	12.59	13.18	12.89
$S_1B_1P_1$	87.93	86.27	87.10	81.27	79.94	80.61	2.56	2.54	2.55	12.89	13.49	13.19
$S_1B_2P_0$	88.30	88.97	88.63	83.57	81.10	82.33	2.53	2.50	2.51	12.78	13.48	13.13
$S_1B_2P_1$	89.17	90.52	89.84	84.78	83.43	84.11	2.58	2.56	2.57	12.94	13.53	13.23
$S_2B_0P_0$	92.11	92.37	92.24	86.31	85.64	85.97	2.48	2.50	2.49	13.17	13.15	13.16
$S_2B_0P_1$	93.17	93.83	93.50	87.58	87.54	87.56	2.54	2.56	2.55	13.18	13.48	13.33
$S_2B_1P_0$	95.00	94.67	94.83	89.17	88.84	89.00	2.53	2.52	2.53	13.19	13.46	13.33
$S_2B_1P_1$	96.97	96.20	96.58	90.62	90.68	90.65	2.57	2.57	2.57	13.45	13.63	13.54
$S_2B_2P_0$	97.95	98.57	98.26	92.34	92.67	92.51	2.60	2.58	2.59	13.48	13.59	13.54
$S_2B_2P_1$	98.70	99.30	99.00	94.15	93.78	93.97	2.65	2.62	2.64	13.65	13.76	13.71
SEm±	***0.13***	***0.04***	***0.07***	***0.16***	***0.34***	***0.19***	***0.05***	***0.04***	***0.03***	***0.15***	***0.14***	***0.10***
CD(P=0.05)	***0.39***	***0.12***	***0.20***	***0.47***	***1.00***	***0.53***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***

in the nutrient availability for plant uptake creating optimum condition for plant growth and development might be responsible for the increased number of pods per plant.

4.2.2 Effect on number of filled pods per plant

4.2.2.1. Effect of sulphur on number of filled pods per plant

Table 4.2 (a) and Fig. 4 presented the effect of sulphur on the number of filled pods per plant. As evident from the table, there was an improved grain filling with increase levels of sulphur application. Application of S_2 (40 kg S ha^{-1}) recorded the highest number of filled pods per plant with 90.03 and 89.86 while S_0 (0 kg S ha^{-1}) was the lowest with 69.10 and 66.55 during 2016 and 2017, respectively. It became apparent from the pooled data that S_2 (40 kg S ha^{-1}) showed the highest number of filled pods per plant having 89.94 while S_0 (0 kg S ha^{-1}) showed the lowest with 67.82. Treatment S_2 was found to be significant over S_0 and S_1.

Sulphur dictates many metabolic and enzymatic processes (Najar *et al*., 2011) and influences the yield attributing chacracters which might be responsible for the increased number of filled pods per plant with increasing dose of sulphur.

4.2.2.2. Effect of boron on number of filled pods per plant

As apparent from Table 4.2 (a) and Fig. 4, the application of boron had a significant influence on the number of filled pods per plant. A gradual increase in the number of filled pod per plant was observed with increased level of boron application. The plots receiving B_2 (2 kg B ha^{-1}) showed the highest number of filled pods per plant having 83.86 and 82.39 while the lowest was observed in plots receiving B_0 (0 kg B ha^{-1}) having 75.95 and 74.67 during 2016 and 2017, respectively. It was evident from the pooled data that B_2 recorded the highest with 83.12 and B_0 was the lowest with 75.31 filled pods per plant on an average. Treatment B_2 was found to be significant over B_1 and B_0 while B_1 was significant over B_0 (control).

The increased in the number of filled pods per plant could be due to the fact that boron regulates many metabolic activities and also pollination which greatly influenced the yield attributing parameters (Chaithra and Hebsur, 2018).

4.2.2.3. Effect of phosphorus solubilizing biofertilizer on number of filled pods per plant

From Table 4.2 (a) and Fig. 4, it has become clear that seed treatment with phosphorus solubilizing biofertilizer (PSB) had a significant effect on the number of filled pods per plant in soybean. Treatment P_1 recorded the highest number of filled pods per plant having 80.71 and 79.55 while P_0 was lowest having 79.21 and 77.52 during 2016 and 2017, respectively. From the pooled data it is evident that P_1 recorded significantly higher number of pods per plant having 80.13 as compared to P_0 which have 78.36 filled pods per plant on an average.

The increased in the number of filled pods per plant might be due to improved P solubilization through phosphate solubilizing micro-organisms which promotes biological N_2 fixation and production of plant growth regulators (Gyaneshwar *et al.*, 1998).

4.2.2.4. Effect of sulphur and boron interaction on number of filled pods per plant

Table 4.2 (b) presented the interaction effect between sulphur and boron on the number of filled pods per plant. The increased level of boron application was found to increase the number of filled pods per plant at all levels of sulphur. The highest number of filled pods per plant was recorded with S_2B_2 having 93.25 and

93.23 while S_0B_0 was the lowest having 63.80 and 61.46 during 2016 and 2017, respectively. From pooled data it became evident that S_2B_2 was highest with 93.24 and S_0B_0 was lowest with 62.63 filled pods per plant on an average. The interaction between sulphur and boron had a significant effect on number of filled pods per plant. Treatment combination S_2B_2 was found to be significant over all other treatment combinations.

The increased in the number of filled pods per plant might be due to the improved growth attributes through optimum plant nutrition which further got translated in yield attributes (Ram *et al*., 2014). Similar findings on interaction effect of sulphur and boron on the number of pods per plant have been reported by Layek *et al*. (2014), Longkumer *et al*. (2017) and Ravi *et al*. (2017).

4.2.2.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on number of filled pods per plant

From Table 4.2 (b), it was clear that increasing the levels of sulphur application up to 40 kg S ha^{-1} increases the number of filled pods per plant. However, when phosphorus solubilizing biofertilizer was applied as seed treatment along with sulphur fertilizer, there was gradual increase in the number of filled pods per plant in soybean. The highest number of filled pods per plant was obtained from treatment S_2P_1 having 90.78 and 90.73 while the lowest was S_0P_0 with 68.21 and 65.06 during 2016 and 2017, respectively. In the pooled data, S_2P_1 recorded 90.73 the highest while S_0P_0 recorded 66.64 the lowest among the different treatments. The interaction between sulphur and phosphorus solubilizing biofertilizer had a significant effect on number of filled pods per plant in soybean. S_2P_1 was found to be significant over all other treatment combinations including control.

The improved growth and yield characteristics like number of filled pods per plant with application of sulphur and phosphorus solubilizing biofertilizer could be attributed to efficient utilization of plant nutrients from the soils through their well established root system and nodulations (Suman *et al*., 2018). Similar finding on the number of pods per plant as influenced by the interaction between sulphur and phosphorus has been reported by Majumdar *et al*. (2001).

4.2.2.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on number of filled pods per plant

As evident from Table 4.2 (b), the highest number of filled pod per plant was observed with B_2P_1 which recorded 84.60 and 83.31 during 2016 and 2017, respectively while in the pooled it was 83.96. The lowest was observed with control treatment B_0P_0 which recorded 75.08 and 73.86 during 2016 and 2017, respectively while in the pooled it had 74.47. The interaction between boron and phosphorus solubilizing biofertilizer had significant effect on the number of filled pods per plant. However, treatment B_2P_1 was found to be significant over all other treatment combinations.

The improved nutrient uptake and growth through increased root nodulation and nitrogenase enzyme activity might be responsible for the increased number of filled pods per plant (Srivastava *et al*., 1998).

4.2.2.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on number of filled pods per plant

From Table 4.2 (c), it has been found that plots receiving treatment combination $S_2B_2P_1$ recorded the highest number of filled pods per plant having 94.15 and 93.97 while $S_0B_0P_0$ was the lowest with 62.79 and 60.46 during 2016 and 2017, respectively. In the pooled data, it became apparent that $S_2B_2P_1$ recorded 93.97 filled pods per plant on an average which was more significant as compared to all other treatments while $S_0B_0P_0$ was the lowest with 61.63 on an average.

The application of sulphur, boron and phosphorus solubilizing biofertilizer increased the nutrient availability for plant uptake favouring optimum plant growth and development. The improved P solubilization through phosphate solubilizing micro-organisms which promotes biological N_2 fixation and production of plant growth regulators (Gyaneshwar *et al*., 1998) and the role of sulphur and boron on many metabolic and enzymatic processes which enhanced the yield attributing parameters (Najar *et al*., 2011; Chaithra and Hebsur, 2018) might be responsible for the increased number of filled pods per plant.

4.2.3 Effect on number of seed per pod

4.2.3.1. Effect of sulphur on number of seed per pod

The effect of sulphur on the number of seed per pod has been presented in Table 4.2 (a) and Fig. 4. The highest number of seed per pod was highest with S_2 having 2.56 both 2016 and 2017 while S_0 was the lowest with 2.42 and 2.40 in 2016 and 2017, respectively. The pooled data revealed that S_2 recorded 2.56 was the highest while S_0 was the lowest with 2.41 seed per pod on an average. S_2 was found to be significant over S_0 and S_1.

Sharma *et al.* (2014) opined that the yield characteristics in soybean increases as a result of improved growth and physiological attributes. Choudhary *et al*. (2014) and Mahmoodi *et al*. (2013) also reported that sulphur application had a significant influence on the yield attributing characteristics in soybean.

Similar results on the number of seed per pod in soybean have been reported by several researchers (Jamal *et al*., 2005, Sharma *et al.*, 2014 and Lakshman *et al*., 2015).

4.2.3.2. Effect of boron on number of seed per pod

Table 4.2 (a) and Fig. 4 presented the effect of boron on the number of seed per pod. It was observed that application of B_2 (2 kg B ha^{-1}) recorded the highest number of seed per pod with 2.55 and 2.54 while the lowest was recorded with B_0 (control) with 2.47 seeds per pod both during 2016 and 2017, respectively. From the pooled data it has become apparent that B_2 recorded the highest number of seeds per pod with an average of 2.54 while the lowest was B_0 with 2.47 seed per pod. The application of boron was found to have a significant effect on the number of seed per pod. However, B_2 was found to be significant over B_1 and B_0.

The increased in the number of seed could be due to application of optimum dose of boron which had a profound effect on the yield parameters through enhanced nutrient uptake, improved photosynthetic efficiency and nutrient translocation (Chaithra and Hebsur, 2018). The results are in accordance with the findings of Layek *et al*. (2014), Chaithra and Hebsur (2018).

4.2.3.3. Effect of phosphorus solubilizing biofertilizer on number of seed per pod

As evident from Table 4.2 (a) and Fig. 4, application of phosphorus solubilizing biofertilizer as seed treatment did not have any significant influence on the number of seed per pod in soybean. However, application of P_1 recorded higher number of seeds per pod with 2.52 and 2.51 as compared to P_0 which recorded 2.50 and 2.48 during 2016 and 2017, respectively while in the pooled data, P_1 was 2.52 and P_0

was 2.49. Similar results on the number of seed per pod have been reported by Devi *et al*. (2012) and Devi *et al*. (2013).

4.2.3.4. Effect of sulphur and boron interaction on number of seed per pod

The interaction effect between sulphur and boron on the number of seed per pod has been presented on Table 4.2 (b). It was observed that application of treatment S_2B_2 recorded the highest number of seed per pod with 2.63 and 2.60 while S_0B_0 recorded the lowest with 2.35 and 2.34 during 2016 and 2017, respectively. In the pooled data, S_2B_2 recorded 2.61 while S_0B_0 recorded 2.34 on an average. As evident from the pooled data, treatment S_2B_1 and S_1B_1 recorded the same having 2.55 numbers of seed per pod on an average. It was observed that the interaction between sulphur and boron did not have any significant effect on the number of seed per pod in soybean. The result is in accordance with the observation of Ram *et al*. (2014). Similar findings on the number of seed per pod in soybean with combined application of sulphur and boron has also been reported by Layek *et al*. (2014) and Longkumer *et al*. (2017).

4.2.3.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on number of seed per pod

Table 4.2 (b) showed the interaction effect of sulphur and phosphorus solubilizing biofertilizer on number of seed per pod in soybean. It has been revealed that application of S_2P_1 recorded the highest number of seed per pod with 2.58 both in 2016 and 2017, while S_0P_0 was the lowest with 2.41 and 2.39 during 2016 and 2017, respectively. The pooled data showed that on an average S_2P_1 recorded 2.58 while S_0P_0 recorded 2.40. It was observed that combined application of sulphur and phosphorus solubilizing biofertilizer slightly improves the number of seed per pod compared to application of sulphur alone. However, there was no significant interaction effect on the number of seed per pod.

4.2.3.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on number of seed per pod

The interaction effect between boron and phosphorus solubilizing biofertilizer on number of seeds per pod has been presented on Table 4.2 (b). It was observed that treatment B_2P_1 recorded the highest number of seeds per pod with 2.58 and 2.56 during 2016 and 2017, respectively while in the pooled it was 2.57. Treatment B_0P_0 (control) recorded the lowest number of seeds per pod with 2.46 and 2.45 during 2016 and 2017, respectively while in the pooled it was 2.46. It was observed that the interaction between boron and phosphorus solubilizing biofertilizer did not have any significant effect on the number of seeds per pod.

4.2.3.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on number of seeds per pod

The overall interaction between sulphur, boron and phosphorus solubilizing biofertilizer interaction on number of seeds per pod has been presented on Table 4.2 (c). It has been revealed from the results that application of $S_2B_2P_1$ recorded the highest number of seeds per pod having 2.65 and 2.62 while $S_0B_0P_0$ was the lowest with 2.35 and 2.33. From the pooled data, it has become evident that $S_2B_2P_1$ recorded highest number of seeds per pod with 2.64 while $S_0B_0P_0$ was the lowest 2.34. From the results obtained from the two years observation, it was clear that there was no significant interaction between the different treatment combinations.

4.2.4 Effect on seed test weight

4.2.4.1. Effect of sulphur on seed test weight

The effect of sulphur on seed test weight has been presented on Table 4.2 (a) and Fig. 4. As evident from the results, increased level of sulphur application had a significant effect on the seed test weight of soybean. It was observed that application of 40 kg S ha^{-1} (S_2) recorded the highest seed test weight with 13.35g and 13.51g while S_0 (control) recorded the lowest with 11.g and 11.91g during 2016 and 2017, respectively. From the pooled data, it has become evident that on an average S_2 recorded higher seed test weight having 13.43g as compared to S_1 and S_0 which recorded 12.94g and 11.90g, respectively. Treatment S_2 was found to be significant over S_1 and S_0.

Lakshman *et al*. (2015) reported that application of sulphur upto 45 kg S ha^{-1} recorded highest seed index. Farhad *et al*. (2010) also observed that application of sulphur increased the seed test weight of soybean. The increased in the seed test weight could be due to improved availability of sulphur which improved the performance of all yield parameters.

4.2.4.2. Effect boron on seed test weight

Table 4.2 (a) and Fig. 4 showed the effect of boron on seed test weight of soybean. It has been observed that application of boron up to 2 kg B ha^{-1} had a significant influence on the seed test weight of soybean. From the table it is evident that application of B_2 recorded the maximum seed test weight having 12.90g and 13.25g while B_0 recorded the lowest with 12.34g and 12.49g during 2016 and 2017, respectively. The pooled data revealed that B_2 recorded the highest seed test weight with an average of 13.08g while B_0 was the lowest with an average of

12.42g. From the results treatment B_2 apparently found to be significant over B_1 and B_0.

The increased in seed test weight could be attributed to the role of boron in the formation of seeds. Layek *et al.* (2014) opined that application of 1.5 kg B ha^{-1} significantly increased the seed index in soybean. Similar result also has been reported by Ismail *et al*. (2013) and Ravi *et al.* (2017).

4.2.4.3. Effect phosphorus solubilizing biofertilizer on seed test weight

The effect of phosphorus solubilizing biofertilizer on seed test weight has been shown in Table 4.2 (a) and Fig. 4. The results revealed that seed treatment with phosphorus solubilizing biofertilizer had a significant influence on the seed test weight of soybean. Treatment P_1 was found to give higher seed test weight having 12.74g and 12.96g as compared to P_0 which recorded 12.55g and 12.78g during 2016 and 2017, respectively. In the pooled data, P_1 recorded 12.85g while P_0 recorded 12.67g on an average. As evident from the results obtained treatment P_1 was found to be significant over P_0.

The significant effect on seed test weight might be due to the fact that phosphorus solubilizing biofertilizer increases the P availability resulting in improved growth and development which ultimately increased the seed weight through improved supply of assimilates to seeds. Similar findings had been reported by Devi *et al*. (2012) and Devi *et al*. (2013).

4.2.4.4. Effect sulphur and boron interaction on seed test weight

The interaction effect between sulphur and boron on seed test weight has been presented on Table 4.2 (b). The results revealed that treatment S_2B_2 recorded the highest seed test weight having 13.57g and 13.68g while S_0B_0 recorded the lowest with 11.37g and 11.43g during 2016 and 2017, respectively. From the pooled data, it has become apparent that on an average S_2B_2 recorded the highest seed test weight with 13.62g while S_0B_0 was lowest with 11.40g. There was no significant interaction effect found between sulphur and boron on the seed test weight.

4.2.4.5. Effect sulphur and phosphorus solubilizing biofertilizer interaction on seed test weight

Table 4.2 (b) showed the interaction effect between sulphur and phosphorus solubilizing biofertilizer on the seed test weight of soybean. From the results it has been found that application of S_2P_1 recorded the highest seed test weight with 13.43g and 13.63g while S_0P_0 recorded the lowest with 11.77g and 11.78g during 2016 and 2017, respectively. The pooled data indicates that S_2P_1 recorded the highest seed test weight with 13.53g while S_0P_0 was the lowest with 11.78g on an average. The interaction effect between boron and phosphorus solubilizing biofertilizer was found to be non significant on the seed test weight.

4.2.4.6. Effect boron and phosphorus solubilizing biofertilizer interaction on seed test weight

From Table 4.2 (b), it has become evident that the interaction effect of B_2P_1 recorded the highest seed test weight with corresponding value of 12.98g and 13.33g while B_0P_0 recorded the lowest with 12.32g and 12.50g during 2016 and 2017, respectively. In the pooled data, B_2P_1 recorded 13.15g while B_0P_0 recorded 12.41g on an average. The interaction between boron and phosphorus solubilizing biofertilizer did not have any significant effect on the seed test weight.

4.2.4.7. Effect sulphur, boron and phosphorus solubilizing biofertilizer interaction on seed test weight

The overall interaction effect between sulphur, boron and phosphorus solubilizing bifertilizer on seed test weight has been presented in Table 4.2 (c). The interaction between all the three factors revealed $S_2B_2P_1$ recorded the highest seed test weight with corresponding value of 13.65 g and 13.76g while $S_0B_0P_0$ (control) recorded the lowest with 11.36g and 11.50g during 2016 and 2017, respectively. In the pooled data $S_2B_2P_1$ recorded 13.71g while $S_0B_0P_0$ recorded 11.43g on an average. It was observed that with increased level of sulphur and boron along with seed treatment with phosphorus solubilizing biofertilizer slightly increases the seed test weight. However, the different treatment combinations did not show any significant effect on the seed test weight.

4.3 Effect on yield of soybean

The findings on the effect of sulphur, boron and phosphorus solubilizing biofertilizer on yield *viz.* biological yield, seed yield, stover yield and harvest index are presented under the following heads:

4.3.1 Effect on biological yield

4.3.1.1. Effect of sulphur on biological yield

The effect of sulphur on the biological yield of soybean has been presented on Table 4.3 (a) and Fig. 5. It has become apparent from the results obtained that application of sulphur up to 40 kg S ha^{-1} had a significant influence on the biological yield of soybean. It was observed that application of S_2 (40 kg S ha^{-1}) recorded the highest biological yield with corresponding value of 49.68 qha^{-1} and 49.44 q ha^{-1}

Table 4.3 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on biological yield, seed yield, stover yield and harvest index

Treatments	Biological yield (q ha^{-1})			Seed yield (q ha^{-1})			Stover yield (q ha^{-1})			Harvest index (%)		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	40.12	39.99	40.05	15.02	15.00	15.01	25.10	24.98	25.04	37.44	37.51	37.47
S_1	43.64	43.57	43.61	16.31	16.57	16.44	27.33	26.99	27.16	37.37	38.03	37.70
S_2	49.68	49.44	49.56	19.62	19.79	19.71	30.06	29.64	29.85	39.46	40.02	39.74
SEm±	***3.86***	***4.91***	***3.12***	***3.12***	***3.54***	***2.36***	***2.39***	***2.14***	***1.61***	***0.09***	***0.04***	***0.05***
CD(P=0.05)	***15.16***	***19.26***	***10.18***	***12.26***	***13.90***	***7.70***	***9.39***	***8.42***	***5.24***	***0.37***	***0.17***	***0.17***
B_0	42.65	42.74	42.70	16.05	16.31	16.18	26.60	26.43	26.52	37.57	38.07	37.82
B_1	44.27	44.19	44.23	16.91	16.98	16.95	27.35	27.21	27.28	38.14	38.35	38.25
B_2	46.52	46.06	46.29	17.99	18.08	18.03	28.53	27.98	28.25	38.55	39.14	38.84
SEm±	***2.59***	***4.81***	***2.73***	***1.65***	***3.81***	***2.08***	***2.46***	***2.99***	***1.94***	***0.07***	***0.06***	***0.04***
CD(P=0.05)	***7.98***	***14.83***	***7.98***	***5.09***	***11.74***	***6.06***	***7.59***	***9.23***	***5.66***	***0.21***	***0.18***	***0.13***
P_0	44.13	43.85	43.99	16.81	16.90	16.86	27.31	26.95	27.13	38.02	38.45	38.23
P_1	44.84	44.81	44.82	17.16	17.35	17.25	27.68	27.46	27.57	38.16	38.59	38.38
SEm±	***2.48***	***3.96***	***2.34***	***2.52***	***3.99***	***2.36***	***1.13***	***1.53***	***0.95***	***0.07***	***0.06***	***0.05***
CD(P=0.05)	***7.36***	***11.78***	***6.70***	***7.49***	***11.85***	***6.77***	***3.35***	***4.56***	***2.73***	***NS***	***NS***	***NS***

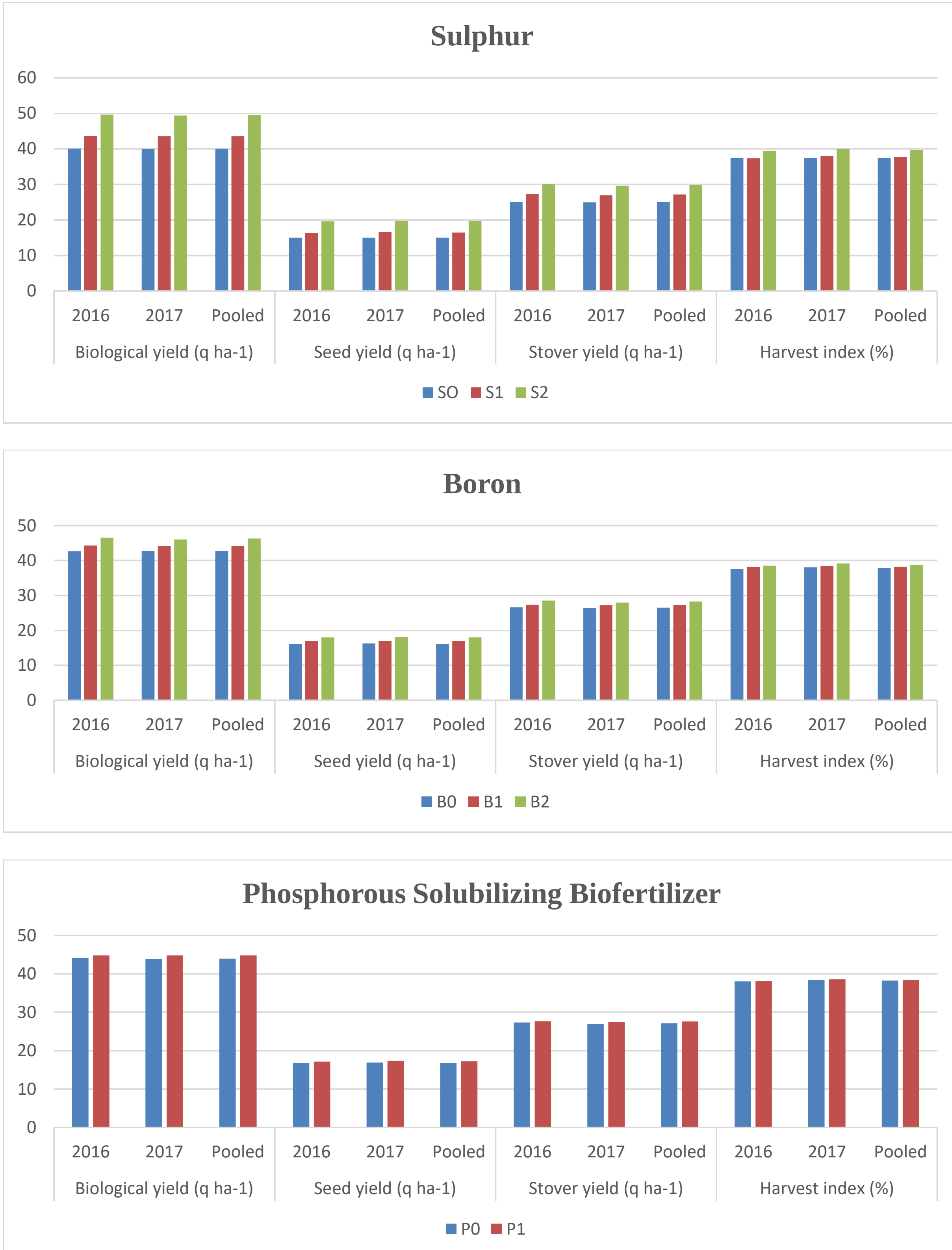


Fig. 5: Effect of sulfur, boron and phosphorus solubilizing biofertilizeron biological yield, seed yield, stover yield and harvest index

while S_0 (0 kg S ha^{-1}) was the least with 40.12 q ha^{-1} and 39.99 q ha^{-1} during 2016 and 2017, respectively. In the pooled data, S_2 recorded 49.56 q ha^{-1} and S_0 recorded 40.05 q ha^{-1} on an average. There was significant difference observed among the different levels of sulphur application on biological yield. However, S_2 level of sulphur application was found to be significant over S_1 and S_0.

The application of sulphur increases the growth and yield attributing parameters in soybean resulting in higher biological yield which could be attributed to the vital role of sulphur in regulating the metabolic and enzymatic processes including respiration and photosynthesis. Jamal *et al*. (2005) observed that highest biological yield in soybean was obtained with application of 40 kg S ha^{-1}. Najar *et al*. (2011) also reported that the grain and stover yield in soybean was increased to the tune of 66.0 and 53.4% with application of 40 kg S ha^{-1}.

4.3.1.2. Effect of boron on biological yield

Table 4.3 (a) and Fig. 5 showed the effect of boron application on biological yield of soybean. As evident from the results, increased level of boron application increases the biological yield of soybean. It has been observed that application of 2 kg B ha^{-1} *i.e*., B_2 gives the highest biological yield which recorded 46.52 q ha^{-1} and 46.06 q ha^{-1} whereas the lowest biological yield was observed with B_0 which recorded 42.65 q ha^{-1} and 42.74 q ha^{-1} during 2016 and 2017, respectively. In the pooled data, B_2 recorded an average of 46.29 q ha^{-1} while B_0 was 42.70 q ha^{-1}. The different levels of boron application showed significant difference on the biological yield. It was apparent that the effect B_2 on biological yield showed significance over B_1 and B_0 levels of boron application.

The deficiency of boron in acid soil is a limiting factor for crop production and the crop could well response to boron application resulting in higher yield.

Improved photosynthetic efficiency, higher nutrient uptake and its translocation to different parts of the plant greatly enhance yield attributing parameters (Chaitra and Hebsur, 2018). Similar results were observed by Devi *et al*. (2012), Ram *et al*. (2014), Shinde *et al*. (2015) and Longkumer *et al*. (2017).

4.3.1.3. Effect of phosphorus solubilizing biofertilizer on biological yield

The effect of phosphorus solubilizing biofertilizer on biological yield has been presented on Table 4.3 (a) and Fig. 5. It has been observed that seed treatment with phosphorus solubilizing biofertilizer *i.e.*, P_1 gives higher biological yield which recorded 44.84 q ha^{-1} and 44.81 q ha^{-1} as compared to P_0 which recorded 44.13 q ha^{-1} and 43.85 q ha^{-1} during 2016 and 2017, respectively. In the pooled data, P_1 recorded 44.82 q ha^{-1} whereas P_0 recorded 43.99 q ha^{-1} on an average. It was found that application of phosphorus solubilizing biofertilizer (P_1) had significant effect biological yield.

The increase in the biological yield could be due to the solubilization of the fixed phosphates in soil by phosphorus solubilizing biofertilizer resulting better growth and ultimately improved yield. Dhage *et al.* (2008) reported that inoculation of *rhizobium* and PSB with 100% RDF recorded the highest biological yield. Devi *et al*. (2013) also observed improved yield in soybean with application of PSB.

4.3.1.4. Effect of sulphur and boron interaction on biological yield

The interaction effect of sulphur and boron on biological yield has been presented on Table 4.3 (b). It was observed that increased level of boron application significantly increases the biological yield of soybean at all levels of

Table 4.3 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on biological yield, seed yield, stover yield and harvest index

Treatments	**Biological yield (q ha^{-1})**			**Seed yield (q ha^{-1})**			**Stover yield (q ha^{-1})**			**Harvest index (%)**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0B_0	38.60	38.49	38.54	14.32	14.25	14.28	24.28	24.24	24.26	37.10	37.02	37.06
S_0B_1	40.41	40.18	40.30	15.21	15.10	15.15	25.20	25.08	25.14	37.64	37.58	37.61
S_0B_2	41.35	41.29	41.32	15.53	15.66	15.59	25.81	25.63	25.72	37.57	37.92	37.75
S_1B_0	42.15	42.50	42.33	15.61	15.96	15.78	26.54	26.54	26.54	37.03	37.56	37.30
S_1B_1	43.03	43.31	43.17	16.09	16.35	16.22	26.94	26.96	26.95	37.39	37.75	37.57
S_1B_2	45.75	44.91	45.33	17.24	17.41	17.32	28.51	27.49	28.00	37.68	38.78	38.23
S_2B_0	47.21	47.23	47.22	18.22	18.72	18.47	28.99	28.51	28.75	38.59	39.63	39.11
S_2B_1	49.36	49.09	49.22	19.45	19.50	19.47	29.91	29.58	29.75	39.40	39.73	39.56
S_2B_2	52.47	51.99	52.23	21.19	21.17	21.18	31.27	30.82	31.04	40.39	40.71	40.55
SEm±	***4.49***	***8.33***	***4.73***	***2.86***	***6.60***	***3.60***	***4.27***	***5.19***	***3.36***	***0.12***	***0.10***	***0.08***
CD(P=0.05)	***13.83***	***25.68***	***13.81***	***8.81***	***20.33***	***10.49***	***13.15***	***15.98***	***9.80***	***0.36***	***0.32***	***0.23***
S_0P_0	39.95	39.77	39.86	14.96	14.90	14.93	24.99	24.87	24.93	37.44	37.46	37.45
S_0P_1	40.29	40.20	40.25	15.08	15.10	15.09	25.20	25.10	25.15	37.43	37.56	37.50
S_1P_0	43.24	43.15	43.19	16.16	16.42	16.29	27.07	26.73	26.90	37.38	38.05	37.71
S_1P_1	44.05	44.00	44.03	16.46	16.73	16.60	27.58	27.26	27.42	37.36	38.02	37.69
S_2P_0	49.19	48.65	48.92	19.31	19.39	19.35	29.88	29.26	29.57	39.24	39.84	39.54
S_2P_1	50.17	50.22	50.20	19.92	20.20	20.06	30.24	30.02	30.13	39.68	40.20	39.94
SEm±	***4.29***	***6.87***	***4.05***	***4.37***	***6.91***	***4.09***	***1.95***	***2.66***	***1.65***	***0.12***	***0.10***	***0.08***
CD(P=0.05)	***12.75***	***20.40***	***11.61***	***12.97***	***20.53***	***11.72***	***5.80***	***7.90***	***4.73***	***NS***	***NS***	***NS***
B_0P_0	42.38	42.36	42.37	15.93	16.17	16.05	26.44	26.18	26.31	37.56	38.09	37.83
B_0P_1	42.93	43.12	43.03	16.16	16.45	16.30	26.76	26.67	26.72	37.59	38.05	37.82
B_1P_0	43.96	43.82	43.89	16.78	16.82	16.80	27.18	27.00	27.09	38.10	38.32	38.21
B_1P_1	44.58	44.56	44.57	17.05	17.14	17.10	27.53	27.42	27.47	38.18	38.39	38.29
B_2P_0	46.04	45.38	45.71	17.72	17.71	17.72	28.32	27.67	27.99	38.40	38.94	38.67
B_2P_1	47.00	46.74	46.87	18.26	18.45	18.35	28.74	28.29	28.52	38.70	39.34	39.02
SEm±	***4.29***	***6.87***	***4.05***	***4.37***	***6.91***	***4.09***	***1.95***	***2.66***	***1.65***	***0.12***	***0.10***	***0.08***
CD(P=0.05)	***12.75***	***20.40***	***11.61***	***12.97***	***20.53***	***11.72***	***5.80***	***7.90***	***4.73***	***NS***	***NS***	***NS***

sulphur than application of sulphur alone. The interaction effect of S_2B_2 gave the highest biological yield which recorded 52.47 q ha^{-1} and 51.99 q ha^{-1} whereas S_0B_0 recorded the lowest with 38.60 q ha^{-1} and 38.49 q ha^{-1} during 2016 and 2017, respectively. From the pooled data, it has become evident that S_2B_2 recorded 52.23 q ha^{-1} on an average which was significantly higher than all other treatments whereas S_0B_0 was the lowest with an average mean of 38.54 q ha^{-1}.

The improved availability of sulphur and boron led to improved plant growth and development which resulted in higher biological yield. Sharma and Singh (2005) opined that sulphur stimulates improved vegetative structure for nutrient absorption and create strong sink through production of assimilates and development of reproductive structure. Ravi *et al*. (2017) observed that boron helps in root nodulation and seed formation. Synergistic interaction between sulphur and boron on yield of soybean was also reported by Longkumer *et al*. (2017).

4.3.1.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on biological yield

Table 4.3 (b) presented the interaction effect of sulphur and phosphorus solubilizing biofertilizer on biological yield. It was observed that application of S_2P_1 recorded the highest biological yield with corresponding value of 5017.61 kg ha^{-1} and 50.22 q ha^{-1} while S_0P_0 was the lowest with 39.95 q ha^{-1} and 39.77 q ha^{-1} during 2016 and 2017, respectively. In the pooled data, treatment S_2P_1 recorded 50.20 q ha^{-1} while S_0P_0 was 39.86 q ha^{-1} on an average. The interaction between sulphur and phosphorus solubilizing biofertilizer has been found to have significant influence on the biological yield. It was observed that application of phosphorus solubilizing biofertilizer as seed treatment at all levels of sulphur application increased the biological yield as compared to application of sulphur alone. All treatment combinations showed significant effect on biological yield over the control treatment S_0P_0. However, treatment S_2P_1 was found to be significant over all other treatment combinations in both the years.

The increased in the biological yield might be due to the role of phosphorus solubilizing biofertilizer in solubilizing the fixed phosphate in soil which helps in development of root biomass and nodulation coupled with improved S availability which ultimately improved the growth and yield attributing parameters. Synergistic interaction effect of sulphur and phosphorus on biological yield was also observed by Dhage *et al*. (2014) and Suman *et al*. (2018). The results are in accordance with the observations of Akter *et al*. (2013).

4.3.1.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on biological yield

From Table 4.3 (b), it was clear that treatment B_2P_1 recorded the highest biological yield with an average of 47.00 q ha^{-1} and 46.74 q ha^{-1} while B_0P_0 was lowest with 42.38 q ha^{-1} and 42.36 q ha^{-1} during 2016 and 2017, respectively. The pooled data showed that B_2P_1 recorded an average of 46.87 q ha^{-1} while B_0P_0 was 42.37 q ha^{-1}. It was observed that application of increased level of boron increase the biological yield. However, when boron was applied along with phosphorus solubilizing biofertilizer the biological yield significantly increased than application of boron alone. Treatment B_2P_1 was found to be significantly higher than other treatment combinations.

Ravi *et al*. (2017) observed that boron helps in root nodulation and seed formation. The application of phosphorus solubilizing biofertilizer helps in solubilizing the fixed phosphate in soil which facilitates root development and nodulation. Devi *et al*. (2012) and Pindkurwar *et al*. (2015) observed that inoculation with PSB gives higher stover and seed yield over control treatment. The positive response of biological yield might be due to the improved availability of both P and B in soil which is usually deficient and a limiting factor in acid soils.

4.3.1.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on biological yield

Table 4.3 (c) showed the overall interaction effect of sulphur, boron and phosphorus solubilizing biofertilizer on biological yield. As evident from the results, treatment $S_2B_2P_1$ recorded the highest biological yield with an average of 53.15 q ha^1 and 53.26 q ha^{-1} while the control treatment $S_0B_0P_0$ recorded the lowest with 38.35 q ha^{-1} and 38.26 q ha^{-1} during 2016 and 2017, respectively. It was observed that application of increasing the levels of boron along with phosphorus solubilizing biofertilizer as seed treatment at all levels of sulphur significantly increased the biological yield. The different treatment combinations showed significant difference over the control treatment $S_0B_0P_0$. However, treatment $S_2B_2P_1$ was found to give significantly higher biological yield as compared to other treatment combinations.

The improved nutrient availability for plant uptake resulted in improved growth and development of the plants and ultimately higher yield. Jamal *et al*. (2005) observed that highest biological yield in soybean was obtained with application of 40 kg S ha^{-1}. Synergistic interaction between sulphur and boron on yield of soybean was reported by Longkumer *et al*. (2017). Synergistic interaction effect of sulphur and phosphorus on biological yield was also observed by Dhage *et al*. (2014) and Suman *et al*. (2018).

Table 4.3 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on biological yield, seed yield, stover yield and harvest index

Treatments	Biological yield (q ha^{-1})			Seed yield (q ha^{-1})			Stover yield (q ha^{-1})			Harvest index (%)		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
$S_0B_0P_0$	38.35	38.26	38.31	14.24	14.16	14.20	24.11	24.09	24.10	37.15	37.03	37.09
$S_0B_0P_1$	38.85	38.71	38.78	14.39	14.33	14.36	24.45	24.38	24.41	37.06	37.02	37.04
$S_0B_1P_0$	40.30	39.88	40.09	15.14	14.92	15.03	25.15	24.96	25.06	37.58	37.41	37.50
$S_0B_1P_1$	40.53	40.49	40.51	15.27	15.28	15.28	25.25	25.20	25.22	37.70	37.75	37.72
$S_0B_2P_0$	41.20	41.17	41.18	15.49	15.61	15.55	25.70	25.55	25.63	37.60	37.94	37.77
$S_0B_2P_1$	41.50	41.41	41.46	15.58	15.70	15.64	25.92	25.71	25.81	37.54	37.91	37.73
$S_1B_0P_0$	41.92	42.08	42.00	15.56	15.89	15.73	26.35	26.19	26.27	37.13	37.77	37.45
$S_1B_0P_1$	42.38	42.93	42.65	15.65	16.03	15.84	26.73	26.89	26.81	36.94	37.36	37.15
$S_1B_1P_0$	42.65	43.10	42.87	15.93	16.36	16.15	26.72	26.73	26.72	37.35	37.97	37.66
$S_1B_1P_1$	43.42	43.53	43.47	16.25	16.33	16.29	27.16	27.19	27.18	37.43	37.53	37.48
$S_1B_2P_0$	45.14	44.26	44.70	16.99	16.99	16.99	28.15	27.27	27.71	37.65	38.40	38.02
$S_1B_2P_1$	46.35	45.55	45.95	17.48	17.83	17.66	28.87	27.71	28.29	37.72	39.16	38.44
$S_2B_0P_0$	46.87	46.73	46.80	18.00	18.45	18.22	28.87	28.27	28.57	38.41	39.48	38.94
$S_2B_0P_1$	47.56	47.73	47.65	18.44	18.98	18.71	29.12	28.74	28.93	38.77	39.78	39.27
$S_2B_1P_0$	48.93	48.49	48.71	19.26	19.18	19.22	29.66	29.30	29.48	39.37	39.57	39.47
$S_2B_1P_1$	49.80	49.68	49.74	19.63	19.81	19.72	30.16	29.86	30.01	39.43	39.89	39.66
$S_2B_2P_0$	51.78	50.72	51.25	20.68	20.52	20.60	31.10	30.19	30.64	39.94	40.47	40.21
$S_2B_2P_1$	53.15	53.26	53.21	21.71	21.81	21.76	31.44	31.45	31.45	40.84	40.95	40.90
SEm±	***7.43***	***11.89***	***7.01***	***7.56***	***11.97***	***7.08***	***3.38***	***4.60***	***2.86***	***0.22***	***0.18***	***0.14***
CD(P=0.05)	***22.08***	***35.34***	***20.11***	***22.47***	***35.55***	***20.30***	***10.05***	***13.68***	***8.19***	***NS***	***NS***	***NS***

4.3.2 Effect on seed yield

4.3.2.1. Effect of sulphur on seed yield

The effect of sulphur on seed yield has been shown in Table 4.3 (a) and Fig. 5. It was observed that increasing the levels of sulphur up to 40 kg ha^{-1} significantly increased the seed yield of soybean. The application of S_2 (40 kg S ha^{-1}) recorded the highest seed yield with an average of 19.62 q ha^{-1} and 19.79 q ha^{-1} while S_0 (0 kg S ha^{-1}) was the lowest with 15.02 q ha^{-1} and 15.00 q ha^{-1} during 2016 and 2017, respectively. In the pooled data, S_2 recorded an average mean of 19.71 q ha^{-1} while S_0 recorded 15.01 q ha^{-1}. Treatment S_2 was found to be significantly higher than treatment S_1 and S_0 in both the years.

The S requirement for soybean is high and has a direct influence on the metabolic activities of the plant which might be responsible for the increased in seed yield. The present findings are in close conformity with findings of Lakshman *et al*. (2015). Positive yield response of soybean to sulphur application were also reported by Sangale and Sonar (2004), Jamal *et al*. (2005), Chauhan *et al*. (2013), Choudhary *et al*. (2014), Reddy *et al.* (2014) and Parakhia *et al*. (2016).

4.3.2.2. Effect of boron on seed yield

It became evident from Table 4.3 (a) and Fig. 4 that application of boron had significant influence on seed yield of soybean. Application of B_2 (2 kg B ha^{1}) has been found to give the highest seed yield with an average of 17.99 q ha^{-1} and 18.08 q ha^{-1} while B_0 (0 kg B ha^{-1}) was the lowest with 16.05 q ha^{-1} and 16.31 q ha^{-1} during 2016 and 2017, respectively. In the pooled data treatment B_2 recorded an average mean of 18.03 q ha^{-1} while B_0 was 16.18 q ha^{-1}. Treatment B_2 was found to be significantly higher than treatment B_1 and B_0.

Flowering and pod setting are positively influence by B resulted in higher number of pod and total pod yield per plant (Chatterjee and Bandyopadhyay, 2017). Yang *et al.* (2004) opined that application of B alleviate Al toxicity and improved the growth characters significantly which could possibly result in higher seed yield. Ravi *et al.* (2017) opined that root nodulation and seed formation process were favourably influence by boron. The improvement in seed yield of soybean with B fertilizer has been reported by Ross *et al.* (2006).

4.3.2.3. Effect of phosphorus solubilizing biofertilizer on seed yield

Table 4.3 (a) and Fig. 4 showed the effect of phosphorus solubilizing biofertilizer on seed yield. It was apparent from the results that phosphorus solubilizing biofertilizer application had a significant effect on the seed yield of soybean. The application of P_1 was found to have higher seed yield with an average of 17.16 q ha^{-1} and 17.35 q ha^{-1} as compared to P_0 which recorded 16.81 q ha^{-1} and 16.90 q ha^{-1} during 2106 and 2017, respectively. In the pooled data, P_1 recorded an average mean of 17.25 q ha^{-1} while P_0 recorded 16.86 q ha^{-1}. Treatment P_1 was found to be significantly higher than P_0 in both years.

The phosphorus solubilizing biofertilizer solubilised the organic and inorganic insoluble phosphate in soil and increased the P availability to plant resulting in better growth and development which might be responsible for higher yield. Improvement in the seed yield with application of PSB has also been reported by Dhage *et al*. (2008), Devi *et al*. (2013) and Pindkurwar *et al*. (2015).

4.3.2.4. Effect of sulphur and boron interaction on seed yield

The interaction effect between sulphur and boron on seed yield has been presented in Table 4.3 (b). It was observed that at all level of sulphur, increasing the levels of boron application increased the seed yield of soybean. The highest seed yield was obtained from S_2B_2 which recorded 21.19 q ha^{-1} and 21.17 q ha^{-1} while the lowest was obtained from S_0B_0 which recorded 14.32 q ha^{-1} and 14.25 q ha^{-1} during 2016 and 2017, respectively. The pooled data revealed that S_2B_2 recorded the highest seed yield with an average mean of 21.18 q ha^{-1} while S_0B_0 was lowest with an average mean of 14.28 q ha^{-1}. The interaction between sulphur and boron was found to have a significant effect on the seed yield of soybean. All the treatments were found to be significant over the control treatment. However, S_2B_2 was found to be significantly yielding higher seed yield as compared to other treatments.

The increased seed yield might be due to improved plant nutrition have favourable effect on growth and development which ultimately got translated to yield parameters like number of pods per plant and finally seed yield. Layek *et al.* (2014), Longkumer *et al*. (2017) and Modhavadiya *et al.* (2018) also observed significant interaction effect of sulphur and boron on seed yield. The present finding is in parallel with the observation of Devi *et al*. (2012) and Ram *et al*. (2014).

4.3.2.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on seed yield

Table 4.3 (b) showed the interaction effect between sulphur and phosphorus solubilizing biofertilizer on seed yield of soybean. The interaction between sulphur and phosphorus solubilizing biofertilizer was found to have a significant effect on seed yield. Application of sulphur along with phosphorus solubilizing biofertilzer as seed treatment increase the seed yield than application of sulphur alone. The highest seed yield was obtained with S_2P_1 which recorded 19.92 q ha^{-1} and 20.20 q ha^{-1} while the lowest seed yield was observed with S_0P_0 which recorded 14.96 q ha^{1} and 14.90 q ha^{-1} during 2016 and 2017, respectively. In the pooled data S_2P_1 recorded 20.06 q ha^{-1} while S_0P_0 recorded 14.93 q ha^1. Treatment S_2P_1 was found to be significantly higher than other treatment combinations.

The demand for P and S is high for pulses and oilseeds. The solubilization of fixed phosphate in soil by phosphorus solubilizing biofertilizer coupled with improved S availability through S application might lead to better development of vegetative and reproductive structure resulting in higher seed yield. Yadav *et al.* (2013), Dhage *et al.* (2014) and Suman *et al.* (2018) reported synergistic effect P and S on soybean seed yield.

4.3.2.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on seed yield

As evident from the results given in Table 4.3 (b), application of B_2P_1 recorded the highest seed yield with 18.26 q ha^{-1} and 18.45 q ha^{-1} whereas B_0P_0 recorded the lowest seed yield with an average of 15.93 q ha^{-1} and 16.17 q ha^{-1} during 2016 and 2017, respectively. In the pooled data, B_2P_1 recorded 18.35 q ha^{-1} and B_0P_0 recorded 16.05 q ha^{-1}. It was observed that increasing the levels of boron along with phosphorus solubilizing biofertilizer application significantly increase the seed yield of soybean. All the different treatment combinations were found to be significant over control treatment, however, B_2P_1 was found to yield significantly higher seed yield.

The increase in the seed yield with application of boron and along with phosphorus solubilizing biofertilizer might be due to the severe deficiency of P and B in the experimental site which poses a major limitation to crop production. Sentimenla *et al.* (2012), Kamboj and Malik (2018) also reported that application of P along with B significantly influence the seed yield.

4.3.2.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on seed yield

The interaction effect between sulphur, boron and phosphorus solubilizing biofertilizer on seed yield has been presented in Table 4.3 (c). It has been found that at all levels of sulphur, increasing the levels of boron along with seed treatment with phosphorus solubilizing biofertilizer significantly increased the seed yield of soybean. As evident from the table, treatment $S_2B_2P_1$ recorded the highest seed yield with an average of 21.71 q ha^{-1} and 21.81 q ha^{-1} whereas $S_0B_0P_0$ (control) was the lowest with 14.24 q ha^{-1} and 14.16 q ha^{-1} during 2016 and 2017, respectively. In the pooled data, $S_2B_2P_1$ recorded 21.76 q ha^{-1} while $S_0B_0P_0$ recorded 14.20 q ha^{-1}. The treatments were found to have significant effect on the seed yield. However, treatment $S_2B_2P_1$ was found to be significantly higher as compared to other treatments including control.

The improvement in nutrient availability through application of S and B along with phosphorus solubilizing biofertilizer might have led to better utilization of nutrients by the plants through their well develop root system and nodulations which in turn resulted in higher seed yield.

4.3.3 Effect on stover yield

4.3.3.1. Effect of sulphur on stover yield

Table 4.3 (a) and Fig. 5 presented the effect of sulphur on stover yield. The result indicates that application of sulphur up to 40 kg ha^{-1} had a significant influence on stover yield. Application of S_2 (40 kg S ha^{-1}) recorded the highest stover yield with an average of 30.06 q ha^{-1} and 29.64 q ha^{-1} while the lowest was recorded with S_0 (0 kg S ha^{-1}) with an average of 25.10 q ha^{-1} and 24.98 q ha^{-1} during 2016 and 2017, respectively. In the pooled data, S_2 recorded an average mean of 29.85 q ha^{-1} while S_0 was 25.04 q ha^{-1}. Treatment S_2 was found to be significant over S_1 and S_0.

The higher stover yield with increased in the level of sulphur application might be through its regulatory effect on the enzymatic and metabolic processes including respiration and photosynthesis resulting in higher yield (Najar *et al.* 2011). Ganeshamurthy (1996), Majumdar *et al.* (2001), Chaurasia *et al.* (2009) also reported that application 40 kg S ha^{-1} was observed to be optimum dose to get the highest stover yield.

4.3.3.2. Effect of boron on stover yield

Table 4.3 (a) and Fig. 5 showed the results on the effect of boron on stover yield. It has been observed that application of B_2 (2 kg B ha^{-1}) recorded the highest stover yield with 28.53 q ha^{-1} and 27.98 q ha^{-1} whereas the lowest stover yield was obtained with B_0 which recorded 26.60 q ha^{-1} and 26.43 q ha^{-1} during 2016 and 2017, respectively. In the pooled data, B_2 recorded 28.25 q ha^{-1} while B_0 was 26.52 q ha^{-1}. It was evident that with increase in the level of B application, the stover yield increased significantly.

Boron deficieny and acidity induced Al toxicity are major limiting factors of crop production Nagaland soils. Yang *et al.* (2004) opined that application of B alleviate Al toxicity and improved the growth characters significantly. The increased in stover yield could be attributed to the vital role of boron in physiological and bio-chemical processes during plant growth resulting higher stover yield. Similar result on stover yield was observed by Sarker *et al.* (2002).

4.3.3.3. Effect of phosphorus solubilizing biofertilizer on stover yield

The result on the effect of phosphorus solubilizing biofertilizer on stover yield has been presented on Table 4.3 (a) and Fig. 5. It was observed that application of phosphorus solubilizing biofertilizer as seed treatment had a significant influence on stover yield. Application of P_1 recorded higher stover yield with an average of 27.68 q ha^{-1} and 27.46 q ha^{-1} as compared to P_0 which recorded 27.31 q ha $^{-1}$ and 26.95 q ha^{-1} during 2016 and 2017, respectively. In the pooled data, P_1 recorded an average mean of 27.57 q ha^{-1} and P_0 recorded 27.13 q ha^{-1}.

The phosphorus solubilizing biofertilizer might have solubilized the phosphate in soil leading to well developed root system and nodulation with consequent improved nitrogen fixation and better utilization of nutrients which in turn resulted in higher stover yield.

4.3.3.4. Effect of sulphur and boron interaction on stover yield

The result on the interaction effect of sulphur and boron on stover yield has been presented on Table 4.3 (b). Increasing the levels of boron application at all levels of sulphur application has been found to have a significant influence on the stover yield than application of sulphur alone. The highest stover yield was observed with S_2B_2 which recorded 31.27 q ha^{-1} and 30.82 q ha^{-1} while lowest stover yield was observed with S_0B_0 which recorded 24.28 q ha^{-1} and 24.24 q ha^{-1} during 2016 and 2017, respectively. In the pooled data, S_2B_2 recorded an average mean of 31.04 q ha^{-1} and S_0B_0 recorded 24.26 q ha^{-1}. Treatment S_2B_2 was found to be significant over other treatment combinations including control.

The improved plant nutrition with the application of sulphur and boron resulted in better growth and yield attributing characters and ultimately higher stover yield. Saxena and Nainwal (2010) also opined that increasing the levels of sulphur and boron significantly increases the seed and stover yield. The observations are in close agreement with the findings of Sarker *et al.* (2002) and Ravi *et al.* (2017).

4.3.3.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on stover yield

Table 4.3 (b) showed the results on the interaction effect between sulphur and phosphorus solubilizing biofertilizer on stover yield. The highest stover yield was observed S_2P_1 which recorded 30.24 q ha^{-1} and 30.02 q ha^{-1} whereas S_2P_0 recorded 24.99 q ha^{-1} and 24.87 q ha^{-1} during 2016 and 2017, respectively. In the pooled data, S_2P_1 recorded 30.13 q ha^{-1} and S_2P_0 recorded 24.98 q ha^{-1}. Combined application of sulphur and phosphorus solubilizing biofertilizer was found to have significant influence on stover yield. Treatment S_2P_1 was found to be significant over all other treatment combinations.

The oilseeds demand for sulphur is high and at the same time, P is deficient in acid soil due to fixation by Al and Fe. As such the application of sulphur and phosphorus solubilizing biofertilizer could have facilitated higher nutrient availability and uptake by plants resulting in improved growth and yield. Shivran *et al.* (2012) revealed that sulphur application along with inoculation of phosphorus solubilizing bacterial increased the stover yield in soybean. Suman *et al.* (2018) also observed synergistic effect between S and P on soybean growth and yield. The present findings are in close conformity with the observations of Akter *et al.* (2013) and Yadav *et al.* (2013).

4.3.3.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on stover yield

The interaction effect between boron and phosphorus solubilizing biofertilizer on stover yield has been presented on Table 4.3 (b). It was observed that application of boron along with phosphorus solubilizing biofertilizer had a significant effect on the stover yield. The highest stover yield was observed with B_2P_1 which recorded 28.74 q ha^{-1} and 28.29 q ha^{-1} during 2016 and 2017, respectively, while in pooled table it was 28.52 q ha^{-1}. The lowest stover yield was observed with B_0P_0 which recorded 26.44 q ha^{-1} and 26.18 q ha^{-1} during 2016 and 2017, respectively, while in pooled table it recorded an average mean of 26.31 q ha^{-1}. Treatment B_2P_1 was observed to be significant over other treatment combinations including control treatment.

The positive response to B and phosphorus solubilizing biofertilizer application might be due to the fact that both P and B are deficient in acid soil. Yang *et al.* (2004) opined that Al toxicity can be alleviated through application of B and improved the growth characters significantly, where Al toxicity is a major limiting factor for crop production in acid soils. Sentimenla *et al.* (2012) also observed that application of phosphorus and boron significantly increases the stover yield in soybean.

4.3.3.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on stover yield

Table 4.3 (c) presented the result on the interaction effect of sulphur, boron and phosphorus solubilizing biofertilizer on stover yield. It has been revealed that application $S_2B_2P_1$ recorded the highest stover yield with 31.44 q ha^{-1} and 31.45 q ha^{-1} whereas $S_0B_0P_0$ (control) recorded the lowest with corresponding value of

24.11 q ha^{-1} and 24.09 kg ha^{-1} during 2016 and 2017, respectively. In the pooled table, $S_2B_2P_1$ recorded an average mean stover yield of 31.45 q ha^{-1} whereas $S_0B_0P_0$ (control) recorded 24.10 q ha^{-1}. Significant difference between the different treatment combinations has been observed. However, application of $S_2B_2P_1$ was found to be significant over other treatment combinations.

Acidity induced deficiency of phosphorus and boron coupled with Al toxicity poses a major limiting factor for crop production and productivity of the land under Nagaland. Furthermore, the demand for sulphur by oilseeds is usually high. As such, application of sulphur and boron along with phosphorus solubilizing biofertilizer might have increased the nutrient availability and its better utilization by plants resulting in better plant growth and consequently improved seed and stover yield.

4.3.4 Effect on harvest index

4.3.4.1. Effect of sulphur on harvest index

Table 4.3(a) and Fig. 5 showed the result on the effect of sulphur on harvest index of soybean. It has become apparent that application of sulphur had a significant influence on the harvest index. It was observed that S_2 (40 kg S ha^{-1}) recorded the maximum harvest index of 39.64% and 40.02% while the minimum harvest index was observed with S_0 having 37.44% and 37.51% during 2016 and 2017. In the pooled table, S_2 recorded an average harvest index of 39.74% and S_0 was 37.47%. S_2 was found to be significant over S_1 and S_0.

The higher harvest index with increasing level of sulphur application might be due to improvement in the seed and stover yield with S application. Similar results were also reported by Sarker *et al.* (2002) and Ram *et al.* (2014).

4.3.4.2. Effect of boron on harvest index

As evident from the Table 4.3 (a) and Fig. 5, application of boron up to 2 kg B ha^{-1} had a significant influence on the harvest index. It was observed that B_2 recorded the highest harvest index of 38.55% and 39.14% while B_0 was the lowest with 37.57% and 38.07% during 2016 and 2017, respectively. In the pooled table, B_2 recorded an average mean harvest index of 38.84% while B_0 was 37.82%. It was observed that increasing the levels of boron application increased the harvest index.

Boron application greatly influenced the seed yield and stover yield which might be responsible for the higher harvest index with increasing level of B application. The present findings are in close agreement with findings of Sarker *et al.* (2002) and Ram *et al.* (2014).

4.3.4.3. Effect of phosphorus solubilizing biofertilizer on harvest index

Effect of phosphorus solubilizing biofertilizer on harvest index has been presented on Table 4.3 (a) and Fig. 5. It has become apparent that application of phosphorus solubilizing biofertilizer (P_1) recorded higher harvest index with 38.16% and 38.59% as compared to P_0 which recorded 38.02% and 38.45% during 2016 and 2017, respectively. In the pooled data, P_1 recorded an average mean harvest index of 38.38% while P_0 was 38.23%. However, it was observed that application of phosphorus solubilizing biofertilizer did not have any significant effect on harvest index.

4.3.4.4. Effect of sulphur and boron interaction on harvest index

The result on the effect of sulphur and boron interaction on harvest index has been presented on Table 4.3 (b). As evident from the result, the interaction between sulphur and boron had a significant effect on the harvest index. The application S_2B_2 recorded the highest harvest index of 40.39% and 40.71% while S_0B_0 recorded the lowest with 37.10% and 37.02% during 2016 and 2017, respectively. In the pooled table, S_2B_2 recorded an average mean of 40.55% and S_0B_0 was 37.06%. Treatment S_2B_2 was found to be significant over other treatment combinations.

Improvement in plant nutrition through sulphur and boron application resulted in higher seed and stover yield which could be responsible for higher harvest index. Sarker *et al.* (2002) and Ram *et al.* (2014) observed significant interaction between sulphur and boron on harvest index in soybean.

4.3.4.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on harvest index

As apparent from Table 4.3 (b), interaction between sulphur and phosphorus solubilizing biofertilizer did not have any significant effect on harvest index. It was observed that S_2P_1 recorded the highest harvest index with 39.68% and 40.20% while S_0P_0 was the lowest with 37.44% and 37.46% during 2016 and 2017, respectively. In the pooled data, S_2P_1 recorded an average mean of 39.94% and S_0P_0 recorded 37.45%.

4.3.4.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on harvest index

Table 4.3 (b) showed the result on the effect of boron and phosphorus solubilizing biofertilizer interaction on harvest index. There was no significant interaction effect on harvest index between boron and phosphorus solubilizing biofertilizer. It has been found that B_2P_1 recorded the highest harvest index with 38.70% and 39.34% during 2016 and 2017, respectively while in the pooled data it was 39.02%. The lowest harvest index was recorded with B_0P_0 with 37.56% and 38.09% during 2016 and 2017, respectively while in the pooled it was 37.83%.

4.3.4.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on harvest index

Table 4.3 (c) showed the interaction effect between sulphur, boron and phosphorus solubilizing biofertilizer on harvest index. It has been found that the interaction between the three factors did not have any significant influence on harvest index. However, the highest harvest index was observed with treatment $S_2B_2P_1$ which recorded 40.84% and 40.95% and in the pooled data it recorded 40.90% on an average. The lowest harvest index was recorded with the control treatment $S_0B_0P_0$ with 37.15% and 37.03% and in the pooled it was 37.09% on an average.

4.4. Effect on nutrient content and uptake

The effect of sulphur, boron and phosphorus solubilizing biofertilizer on the nutrient content and uptake by seeds and stover are discussed below under the following headings:

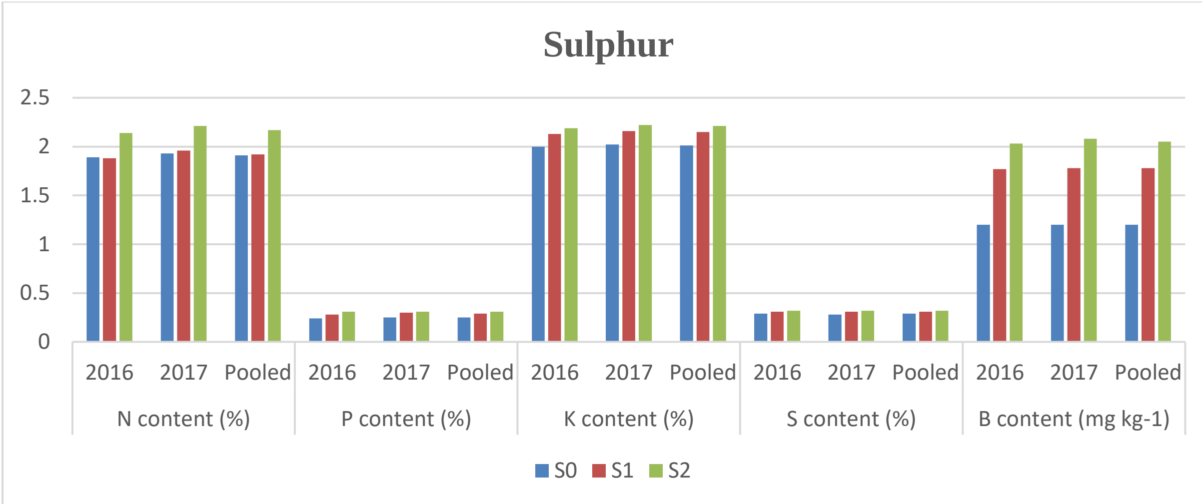
4.4.1. Effect on N, P, K, S and B content in stover

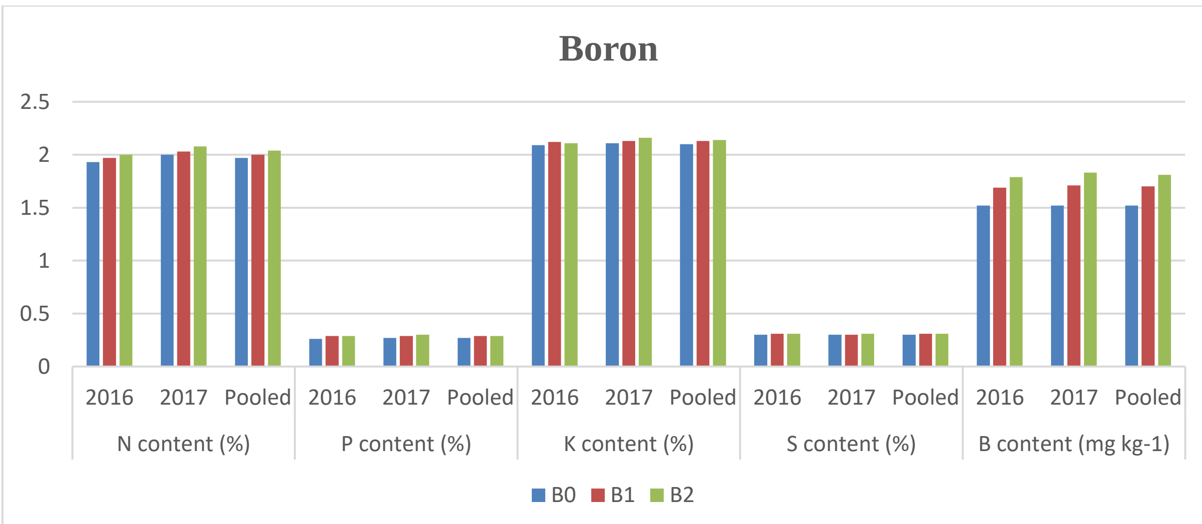
4.4.1.1. Effect of sulphur on N, P, K, S and B content in stover

The effect of sulphur on N, P, K, S and B content in stover has been presented in Table 4.4.1 (a) and Fig. 6. The results revealed that successive increased in the levels of sulphur application had a significant effect on the N, P, K, S and B content in stover. The highest N content was observed when S_2 was applied which recorded 2.14% and 2.21% with pooled value of 2.18% during 2016 and 2017,

Table 4.4.1 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on N, P, K, S and B content in stover

Treatments	N content (%)			P content (%)			K content (%)			S content (%)			B content (mg kg^{-1})		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	1.89	1.93	1.91	0.24	0.25	0.25	2.00	2.02	2.01	0.29	0.28	0.29	1.20	1.20	1.20
S_1	1.88	1.96	1.92	0.28	0.30	0.29	2.13	2.16	2.15	0.31	0.31	0.31	1.77	1.78	1.78
S_2	2.14	2.21	2.17	0.31	0.31	0.31	2.19	2.22	2.21	0.32	0.32	0.32	2.03	2.08	2.05
SEm±	***0.007***	***0.009***	***0.006***	***0.008***	***0.006***	***0.005***	***0.007***	***0.004***	***0.004***	***0.003***	***0.003***	***0.002***	***0.010***	***0.011***	***0.007***
CD(P=0.05)	***0.027***	***0.037***	***0.019***	***0.030***	***0.025***	***0.016***	***0.027***	***0.014***	***0.013***	***0.013***	***0.013***	***0.008***	***0.038***	***0.041***	***0.023***
B_0	1.93	2.00	1.97	0.26	0.27	0.27	2.09	2.11	2.10	0.30	0.30	0.30	1.52	1.52	1.52
B_1	1.97	2.03	2.00	0.29	0.29	0.29	2.12	2.13	2.13	0.31	0.30	0.31	1.69	1.71	1.70
B_2	2.00	2.08	2.04	0.29	0.30	0.29	2.11	2.16	2.14	0.31	0.31	0.31	1.79	1.83	1.81
SEm±	***0.013***	***0.016***	***0.010***	***0.007***	***0.004***	***0.004***	***0.007***	***0.007***	***0.005***	***0.002***	***0.002***	***0.001***	***0.008***	***0.008***	***0.006***
CD(P=0.05)	***0.040***	***0.048***	***0.030***	***0.020***	***0.011***	***0.011***	***0.022***	***0.021***	***0.014***	***0.006***	***0.006***	***0.004***	***0.025***	***0.026***	***0.017***
P_0	1.95	2.02	1.99	0.27	0.28	0.27	2.10	2.13	2.11	0.30	0.30	0.30	1.63	1.66	1.65
P_1	1.99	2.05	2.02	0.29	0.30	0.29	2.12	2.14	2.13	0.31	0.31	0.31	1.70	1.72	1.71
SEm±	***0.007***	***0.007***	***0.005***	***0.004***	***0.004***	***0.003***	***0.005***	***0.004***	***0.003***	***0.001***	***0.002***	***0.001***	***0.008***	***0.008***	***0.006***
CD(P=0.05)	***0.021***	***0.022***	***0.015***	***0.012***	***0.012***	***0.008***	***0.014***	***0.013***	***0.009***	***0.004***	***0.005***	***0.003***	***0.024***	***0.023***	***0.016***





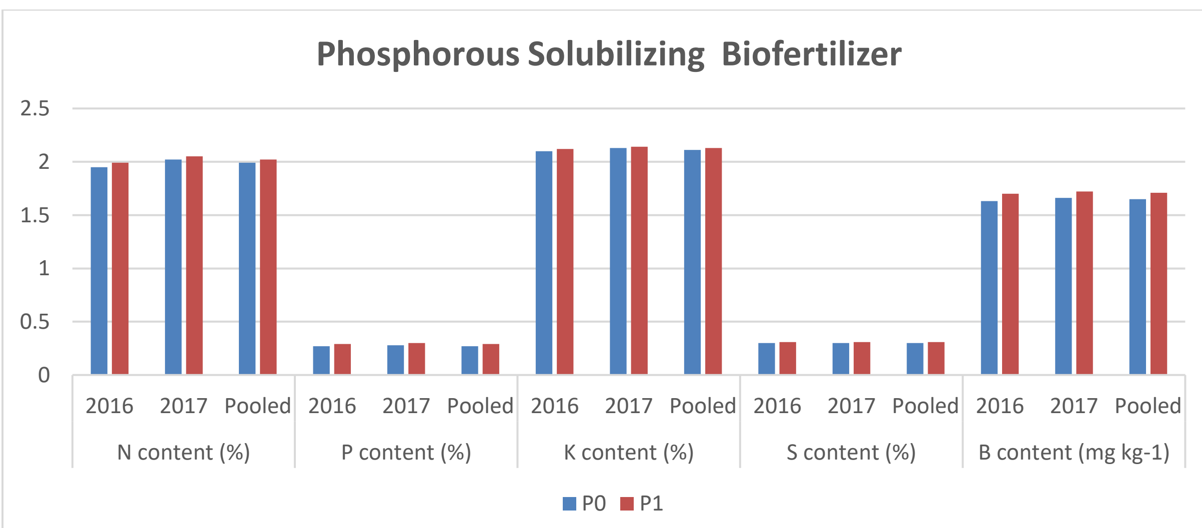


Fig.6: Effect of sulfur, boron and phosphorus solubilizing biofertilizeron N, P, K, S and B content in stover

respectively whereas, the lowest N content in stover was observed with (S_1) during 2016 which recorded 1.88% and S_0 with 1.94% during 2017 while in the pooled S_0 was lowest with 1.91%. The highest P content in stover was observed with S_2 which recorded 0.31% both during 2016 and 2017 and in the pooled data. The lowest P content in stover was 0.24% and 0.25% during 2016 and 2017, respectively by the control treatment (S_0) with a pooled vale of 0.25%. The K content in stover was highest when S_2 was applied which recorded 2.19% and 2.23% during 2016 and 2017, respectively with a pooled vale of 2.21%. The lowest K content in stover was observed with treatment S_0 which recorded 2.00% and 2.01% during 2016 and 2017, respectively with a pooled value of 2.01%. There was gradual increased in the S content in the stover with increasing level of sulphur application. The highest S content in stover was recorded when S_2 level of sulphur was applied which recorded 0.32% both in 2016 and 2017 and in the pooled. The lowest S content was observed when no sulphur was applied *i.e.,* S_0 which recorded 0.29% and 0.28% during 2016 and 2017, respectively with a pooled value of 0.29%. Increasing the S level upto 40 kg S ha^{-1} *i.e.,* S_2 recorded the highest B content in stover with 2.03 mg kg^{-1} and 2.08 mg kg^{-1} during 2016 and 2017, repectively with pooled value of 2.05 mg kg^{-1}. The lowest B content in stover was obtained from control treatment (S_0) with a value of 1.20 mg kg^{-1} in both the years and in pooled.

The results are in accordance with Majumdar *et al.* (2001) and Najar *et al.* (2011) who reported that the nutrient N, P and S content in soybean stover was significantly increased with sulphur fertilization. Pal and Phogat (2005) also observed significant increase in N, P, K, S and B content of mustard with application of sulphur. Biswas *et al.* (2006) also observed that application of sulphur increases the N, K, S and B content in soybean significantly. The increase in effective number and size of root nodules facilitating better N_2 fixation could have attributed to increased N content in stover (Ganeshamurthy and Reddy, 2000). The S fertilization might have favourable effect on adsorption of other elements by the plants leading to significant increase in P content in stover. Patel and Zinzala (2018) observed positive impact on K uptake by soybean through sulphur application thereby increasing the K content in the stover. The significant increased in S content in stover could be attributed to application of adequate amount of sulphur resulting in enhanced absorption and translocation of sulphur by the plants (Shrivastava *et al.,* 2000). Sulphur fertilization must have contributed to improved root growth thereby increasing the uptake of B by the plants and its content in the stover in soybean.

4.4.1.2. Effect of boron on N, P, K, S and B content in stover

Table 4.41 (a) and Fig. 6 presented the effect of boron on the N, P, K, S and B content in stover. From the results obtained, it became evident that increasing the levels of boron application had a significant influence on the N, P, K, S and B content in stover. The highest N content in stover was observed with B_2 which recorded 2.00% and 2.08% during 2016 and 2017, respectively with pooled value of 2.18 while the lowest was observed with B_0 which recorded 1.94% and 2.00% during 2016 and 2017, respectively with pooled value of 1.97%. The highest P content in stover was observed with B_1 and B_2 which recorded 0.29% during 2016 and B_2 with a P content of 0.30% during 2017. In the pooled data both B_1 and B_2 obtained the same P content of 0.29% indicating that they are at par with each other. The lowest P content in stover was observed in treatment B_0 (control) which recorded 0.26% and 0.27% during 2016 and 2017, respectively with a pooled value of 0.27%. During 2016, the highest K content in stover was observed with treatment B_1 which recorded 2.12% while in 2017 B_2 obtained the highest K content of 2.17%. The lowest K content in stover was obtained from treatment B_0 with 2.09%

and 2.11% during 2016 and 2017, respectively. In the pooled data, B_2 recorded the highest K content of 2.14% while B_0 was lowest with 2.10%. The highest S content was observed with B_1 and B_2 which recorded 0.31% in 2016 while B_2 was highest with 0.32% during 2017. In the pooled data both B_1 and B_2 recorded 0.31% indicating that they are at par. The lowest S content was observed in the control treatment B_0 which recorded 0.30% both during 2016 and 2017 and in the pooled. Increasing the B level was found to increase the B content in stover and the highest B content was observed with B_2 which recorded 1.79 mg kg^{-1} and 1.83 mg kg^{-1} in 2016 and 2017, respectively with pooled value of 1.81 mg kg^{-1}.

The results are in agreement with the findings of Patel and Zinzala (2018) who also observed that boron application contributes to significant increase in N, P, K, S and B content in plants.The significant increased N content in stover could be attributed to the favourable effect of boron application on root nodulation and improved N_2 fixation thereby increasing the N content in the stover (Patel and Zinzala, 2018). Significantly higher content of P and K in stover with boron application might be due to its positive effect on absorption of nutrients by the plants from the soil with improved plant growth rate through balanced plant nutrition. Boron deficiency is often encountered under acidic soil and its application might have enhanced its availability and increased root activity resulting in higher nutrient uptake by the plants which contributed to the significant increase in the content of S and B in the stover.

4.4.1.3. Effect of phosphorus solubilizing biofertilizer on N, P, K, S and B content in stover

The effect of phosphorus solubilizing biofertilizer on N, P, K, S and B content in stover has been shown in Table 4.4.1 (a) and Fig. 6. The results revealed that seed inoculation with phosphorus solubilizing biofertilizer significantly influence the N, P, K, S and B content in stover. Higher N, P K content in stover was observed when P_1 was applied which recorded corresponding N, P K content of 1.99% and 2.05%, 0.29% and 0.30% and 2.12% and 2.14% during 2016 and 2017, respectively with corresponding pooled value of 2.02%, 0.29% and 2.13%, respectively. Lower N, P, K content in stover was observed in uninoculated seeds (P_0) which recorded corresponding value of 1.95% and 2.03%, 0.27% and 0.28% and 2.10% and 2.13% during 2016 and 2017, respectively with pooled value of 1.99%, 0.27% and 2.12%. Similarly higher S content was observed with P_1 which recorded 0.31% both in 2016 and 2017 and in the pooled while P_0 recorded lower S content in stover with 0.30% and 0.31% during 2016 and 2017, respetively with pooled value of 0.30%. The results obtained indicates that seed treatment with phosphorus solubilizing biofertilizer (P_1) recorded higher B content of 1.70 mg kg^{-1} and 1.72 mg kg^{-1} in stover during 2016 and 2017, respectively with a pooled value of 1.71 mg kg^{-1} as compared to control (P_0) which recorded 1.63 mg kg^{-1} and 1.66 mg kg^{-1} with a pooled value of 1.65 mg kg^{-1} during 2016 and 2017, respectively.

Phosphorus deficiency is a major constraint under acidic soil condition due to phosphate fixation. As such application of phosphorus solubilizing biofertilizer might have solubizes the insoluble phosphate present in the soil which increases its availability to the plants. Improved root growth and activity with enhanced phosphorus availability facilitates higher uptake of nutrients from the soil which could have contributed to the significant increase in the N, P, K, S and B content in the stover. Sandeep *et al.* (2008) observed higher uptake of nutrients by soybean with application of phosphate solubilizing microorganisms (PSM).

4.4.1.4. Effect of sulphur and boron interaction on N, P, K, S and B content in stover

The interaction effect between sulphur and boron on N, P, K, S and B content in stover has been presented in Table 4.4.1 (b). Increasing the levels of boron and sulphur application was found to have a significant influence on the nutrient N, K, S and B content in the stover. The highest N content was obtained from treatment S_2B_2 which recorded 2.23% and 2.28%, 0.31% during 2016 and 2017 with corresponding pooled value of 2.26%. The lowest N content in stover was observed with S_1B_0 which recorded 1.86% during 2016 while during 2017 S_0B_1 recorded the lowest N content of 1.91%. In pooled data S_1B_0 recorded the lowest N content of 1.89%. The K content in stover was highest with treatment S_2B_1 during 2016 which recorded 2.20% while in 2017 treatment S_2B_0 recorded highest K content of 2.24% in stover. In the pooled data S_2B_0 and S_2B_1 recorded the highest K content of 2.21% while S_2B_2 was observed to be statistically at par with them. The lowest K content in stover was observed with treatment S_0B_1 which recorded 1.98% and 2.01% during 2016 and 2017, respectively with pooled value of 1.99%. The highest S content in stover was observed with treatment S_2B_0, S_2B_1, and S_2B_2 all recorded 0.32% during 2016 while during 2017 treatment combination S_1B_2, S_2B_0, and S_2B_1 recorded the highest S content of 0.32%. In the pooled data, S_2B_0, S_2B_1 and S_2B_2 all recorded S content in stover of 0.32% indicating that they are statistically at par with each other. The B content in stover was observed to increase with increased level of S and B fertilization and the highest B content in stover was observed with treatment S_2B_2 which recorded 2.07 mg kg^{-1} and 2.12 mg kg^{-1} during 2016 and 2017 respectively with pooled value of 2.09 mg kg^{-1}. The lowest B content was observed where no S and B were applied *i.e.*, S_0B_0 which recorded 0.95 mg kg^{-1} and 0.94 mg kg^{-1} during 2016 and 2017, respectively with apooled value of 0.94 mg kg^{-1}.

Table 4.4.1 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on N, P, K, S and B content in stover

Treatments	N content (%)			P content (%)			K content (%)			S content (%)			B content (mg kg^{-1})		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
S_0B_0	1.91	1.96	1.93	0.22	0.23	0.23	2.00	2.02	2.01	0.26	0.26	0.26	0.95	0.94	0.94
S_0B_1	1.88	1.91	1.89	0.25	0.24	0.25	1.98	2.01	1.99	0.30	0.29	0.29	1.24	1.24	1.24
S_0B_2	1.88	1.94	1.91	0.26	0.27	0.26	2.01	2.05	2.03	0.30	0.30	0.30	1.43	1.43	1.43
S_1B_0	1.86	1.92	1.89	0.26	0.28	0.27	2.08	2.08	2.08	0.31	0.31	0.31	1.64	1.59	1.61
S_1B_1	1.88	1.96	1.92	0.29	0.30	0.30	2.17	2.18	2.18	0.31	0.31	0.31	1.80	1.81	1.80
S_1B_2	1.89	2.02	1.95	0.30	0.31	0.30	2.15	2.22	2.18	0.30	0.32	0.31	1.88	1.95	1.91
S_2B_0	2.04	2.12	2.08	0.30	0.31	0.31	2.19	2.24	2.21	0.32	0.32	0.32	1.99	2.04	2.02
S_2B_1	2.15	2.24	2.19	0.32	0.31	0.32	2.20	2.22	2.21	0.32	0.32	0.32	2.03	2.08	2.05
S_2B_2	2.23	2.27	2.25	0.31	0.32	0.32	2.18	2.22	2.20	0.32	0.31	0.32	2.07	2.12	2.09
SEm±	***0.023***	***0.027***	***0.018***	***0.011***	***0.006***	***0.007***	***0.012***	***0.012***	***0.009***	***0.003***	***0.003***	***0.002***	***0.014***	***0.015***	***0.010***
CD(P=0.05)	***0.070***	***0.083***	***0.052***	***NS***	***NS***	***NS***	***0.037***	***0.037***	***0.025***	***0.010***	***0.011***	***0.007***	***0.044***	***0.045***	***0.030***
S_0P_0	1.89	1.93	1.91	0.22	0.23	0.23	1.99	2.01	2.00	0.28	0.28	0.28	1.15	1.16	1.16
S_0P_1	1.89	1.94	1.92	0.27	0.26	0.26	2.01	2.03	2.02	0.29	0.29	0.29	1.26	1.24	1.25
S_1P_0	1.86	1.94	1.90	0.28	0.29	0.28	2.13	2.15	2.14	0.31	0.31	0.31	1.74	1.74	1.74
S_1P_1	1.90	1.99	1.94	0.29	0.31	0.30	2.14	2.17	2.15	0.31	0.31	0.31	1.80	1.82	1.81
S_2P_0	2.11	2.19	2.15	0.30	0.31	0.30	2.18	2.22	2.20	0.32	0.32	0.32	2.01	2.07	2.04
S_2P_1	2.17	2.23	2.20	0.32	0.32	0.32	2.20	2.23	2.21	0.32	0.32	0.32	2.05	2.09	2.07
SEm±	***0.012***	***0.013***	***0.009***	***0.007***	***0.007***	***0.005***	***0.008***	***0.007***	***0.005***	***0.003***	***0.003***	***0.002***	***0.014***	***0.014***	***0.010***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
B_0P_0	1.93	1.99	1.96	0.26	0.27	0.26	2.08	2.10	2.09	0.29	0.29	0.29	1.48	1.49	1.49
B_0P_1	1.94	2.01	1.98	0.27	0.28	0.27	2.10	2.12	2.11	0.30	0.30	0.30	1.57	1.56	1.56
B_1P_0	1.96	2.02	1.99	0.27	0.28	0.27	2.11	2.13	2.12	0.31	0.30	0.30	1.67	1.67	1.67
B_1P_1	1.99	2.05	2.02	0.30	0.30	0.30	2.12	2.14	2.13	0.31	0.31	0.31	1.71	1.75	1.73
B_2P_0	1.98	2.05	2.01	0.27	0.29	0.28	2.10	2.15	2.13	0.31	0.31	0.31	1.74	1.81	1.78
B_2P_1	2.03	2.10	2.07	0.30	0.31	0.31	2.13	2.17	2.15	0.31	0.31	0.31	1.83	1.85	1.84
SEm±	***0.012***	***0.013***	***0.009***	***0.007***	***0.007***	***0.005***	***0.008***	***0.007***	***0.005***	***0.003***	***0.003***	***0.002***	***0.014***	***0.014***	***0.010***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***

The secondary nutrient sulphur and micronutrient boron are usually neglected nutrients under traditional fertilizer application for crop cultivation. Therefore, their application might have contributed to balanced plant nutrition and consequently vigour plant growth which prompted higher nutrient absorption from the soil and its translocation to different parts of the plant thereby increasing the N, K, S and B content in the stover. Ganie *et al.* (2014) opined that synergistic interaction effect exist between sulphur and boron which increases the N, P, K, S and B content in French bean stover significantly.

On the other hand, it was found that the interaction between sulphur and boron did not have any significant influence on the P content in stover. The treatment S_2B_1 recorded the highest P content of 0.32% during 2016 while in 2017 S_2B_2 recorded highest P content of 0.32%. In the pooled data both S_2B_1 and S_2B_2 recorded P content of 0.32%. The lowest P content in stover was observed from the control treatment S_0B_0 which recorded 0.22% and 0.23% during 2016 and 2017, respectively with a pooled value of 0.23%.

4.4.1.5. Effect of sulphur and phosphorus solubilizing biofertilizer on N, P, K, S and B content in stover

The results on the interaction effect between sulphur and phosphorus solubilizing biofertilizer on N, P, K, S and B content in stover has been depicted in Table 4.4.1 (b). The results obtained clearly revealed that the interaction between sulphur and phosphorus solubilizing biofertilizer did not have any significant effect on N, P, K, S and B content in stover. The highest N, P, K content in stover was observed with treatment S_2B_2 which recorded 2.17% and 2.23%, 0.32% and 0.32%, 2.20% and 2.23% during 2016 and 2017, respectively with pooled values of 2.20%, 0.32% and 2.21% accordingly. The lowest N content in stover was observed with S_1P_0 which recorded 1.86% during 2016 whereas in 2017 S_0P_0 recorded the lowest N content of 1.91% in stover while in the pooled data S_1P_0 recorded the lowest N content of 1.90%. The lowest P and K content was observed from control S_0P_0 which recorded 0.22% and 0.23%, and 1.99% and 2.01%, respectively during 2016 and 2017 with pooled value of 0.23% and 2.00%, respectively. The treatment combination S_2P_0 and S_2P_1 recorded the highest S content in stover with the same value of 0.32% both during 2016 and 2017 and in the pooled. The lowest S content in stover was obtained from the control treatment S_0P_0 which recorded 0.28% both during 2016 and 2017 and in pooled. The highest B content in stover was observed from treatment S_2P_1 which recorded 2.05 mg kg^{-1} and 2.09 mg kg^{-1} with a pooled value of 2.07 mg kg^{-1} during 2016 and 2017, respectively while the lowest was observed with control treatment S_0P_0 which recorded 1.15 mg kg^{-1} and 1.16 mg kg^{-1} during 2016 and 2017, respectively with a pooled value of 1.16 mg kg^{-1}.

4.4.1.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B content in stover

Table 4.4.1 (b) presented the interaction effect between boron and phosphorus solubilizing biofertilizer on N, P, K, S and B content in stover. The results revealed that there was no significant interaction between the two on the nutrient content in stover. The highest N, P and K content in stover was observed with treatment B_2P_0 which recorded 2.03% and 2.10%, 0.30% and 0.31%, and 2.13% and 2.17% during 2016 and 2017, respectively with pooled values of 2.07%, 0.31% and 2.17%, respectively. The lowest N, P and K content was observed in control B_0P_0 which recorded corresponding values of 1.93% and 1.99%, 0.26% and 0.27%, and 2.08% and 2.10% during 2016 and 2017, respectively with corresponding pooled value of 1.96%, 0.26% and 2.09%, respectively. The highest S content in stover was observed from treatment B_1P_0, B_1P_1, B_2P_0 and B_2P_1 where all recorded the same value of 0.31% while in 2017 treatment B_1P_1, B_2P_0 and B_2P_1 S content of 0.31% and in pooled B_1P_1, B_2P_0 and B_2P_1 recorded the highest S content of 0.31%. The lowest S content was observed from B_0P_0 (control) which recorded 0.29% both in 2016 and 2017 and in the pooled. The B content in stover was highest with treatment B_2P_1 which recorded 1.83 mg kg^{-1} and 1.85 mg kg^{-1} during 2016 and 2017, respectively with pooled value of 1.84 mg kg^{-1} while lowest B content was observed from control treatment B_0P_0 with values of 1.48 mg kg^{-1} and 1.49 mg kg^{-1} during 2016 and 2017, respectively and pooled value of 1.49 mg kg^{-1}.

4.4.1.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B content in stover

The interaction effect of sulphur, boron and phosphorus solubilizing biofertilizer on N, P, K, S and B content in stover has been shown in Table 4.4.1 (c). The highest N content in stover was obtained from treatment $S_2B_2P_1$ which recorded 2.26% and 2.28% with a pooled value of 2.27% during 2016 and 2017, respectively. The lowest N content was observed with treatment $S_1B_0P_0$ and $S_1B_0P_1$ where both recorded 1.86% in 2016 while in 2017 $S_1B_0P_0$ recorded the lowest N content of 1.92% in stover. In pooled data, both treatment $S_1B_0P_0$ and $S_1B_0P_1$ recorded 1.89%. The P content in stover was highest with treatment combination $S_2B_1P_1$ and $S_2B_2P_1$ where both recorded 0.33% and 0.32%, respectively during 2016 and 2017 while in pooled $S_2B_2P_1$ was highest with 0.33%. The lowest P content in stover was obtained from control treatment $S_0B_0P_0$ which recorded 0.21% and 0.22% with pooled value of 0.21% during 2016 and 2017, respectively. The highest K content in stover was observed with treatment $S_2B_0P_1$, $S_2B_1P_1$ and $S_2B_2P_1$ where all recorded 2.20% during 2016 while $S_2B_0P_1$

Table 4.4.1 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on N, P, K, S and B content in stover

Treatments	N content (%)			P content (%)			K content (%)			S content (%)			B content (mg kg^{-1})		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
$S_0B_0P_0$	1.91	1.95	1.93	0.21	0.22	0.21	2.01	2.02	2.02	0.25	0.25	0.25	0.90	0.92	0.91
$S_0B_0P_1$	1.91	1.96	1.93	0.23	0.24	0.24	1.99	2.02	2.00	0.27	0.27	0.27	1.00	0.96	0.98
$S_0B_1P_0$	1.87	1.90	1.89	0.22	0.22	0.22	1.98	2.00	1.99	0.29	0.27	0.28	1.19	1.18	1.18
$S_0B_1P_1$	1.90	1.91	1.90	0.29	0.26	0.28	1.99	2.01	2.00	0.31	0.30	0.30	1.28	1.30	1.29
$S_0B_2P_0$	1.88	1.93	1.90	0.24	0.26	0.25	1.98	2.02	2.00	0.30	0.30	0.30	1.36	1.40	1.38
$S_0B_2P_1$	1.87	1.95	1.91	0.28	0.28	0.28	2.04	2.07	2.06	0.30	0.30	0.30	1.49	1.46	1.48
$S_1B_0P_0$	1.86	1.92	1.89	0.26	0.28	0.27	2.06	2.06	2.06	0.31	0.31	0.31	1.58	1.53	1.56
$S_1B_0P_1$	1.86	1.93	1.89	0.27	0.29	0.28	2.10	2.10	2.10	0.31	0.31	0.31	1.69	1.65	1.67
$S_1B_1P_0$	1.88	1.95	1.91	0.28	0.30	0.29	2.17	2.17	2.17	0.31	0.31	0.31	1.79	1.77	1.78
$S_1B_1P_1$	1.89	1.96	1.93	0.29	0.31	0.30	2.18	2.19	2.18	0.31	0.31	0.31	1.81	1.84	1.83
$S_1B_2P_0$	1.85	1.95	1.90	0.30	0.29	0.29	2.15	2.23	2.19	0.30	0.32	0.31	1.84	1.91	1.87
$S_1B_2P_1$	1.94	2.08	2.01	0.31	0.32	0.31	2.14	2.22	2.18	0.30	0.32	0.31	1.91	1.98	1.95
$S_2B_0P_0$	2.01	2.09	2.05	0.30	0.30	0.30	2.17	2.23	2.20	0.32	0.32	0.32	1.96	2.02	1.99
$S_2B_0P_1$	2.06	2.14	2.10	0.31	0.31	0.31	2.20	2.24	2.22	0.32	0.32	0.32	2.02	2.07	2.04
$S_2B_1P_0$	2.11	2.21	2.16	0.31	0.31	0.31	2.19	2.22	2.21	0.32	0.32	0.32	2.03	2.06	2.05
$S_2B_1P_1$	2.18	2.27	2.23	0.33	0.32	0.32	2.20	2.22	2.21	0.32	0.32	0.32	2.03	2.10	2.06
$S_2B_2P_0$	2.20	2.27	2.24	0.29	0.31	0.30	2.17	2.21	2.19	0.31	0.31	0.31	2.04	2.14	2.09
$S_2B_2P_1$	2.26	2.28	2.27	0.33	0.32	0.33	2.20	2.23	2.21	0.32	0.32	0.32	2.09	2.10	2.10
SEm±	***0.021***	***0.022***	***0.015***	***0.012***	***0.012***	***0.008***	***0.014***	***0.013***	***0.009***	***0.004***	***0.005***	***0.003***	***0.024***	***0.024***	***0.017***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***

recorded the highest with 2.24% during 2017 and in pooled $S_2B_0P_1$ was highest with 2.22%. The lowest K content in stover was observed with plots receiving treatment $S_0B_1P_0$ and $S_0B_2P_0$ where both recorded 1.98% during 2016 while in 2017 $S_0B_1P_0$ recorded the lowest K content of 2.00% and in the pooled $S_0B_1P_0$ recorded the lowest with 1.99%. In 2016, treatment $S_2B_0P_0$, $S_2B_0P_1$, $S_2B_1P_0$, $S_2B_1P_1$ and $S_2B_2P_1$ obtained the highest S content in stover where all the treatment recorded 0.32% while in 2017 treatment $S_1B_2P_0$, $S_1B_2P_1$, $S_2B_0P_0$, $S_2B_0P_1$, $S_2B_1P_0$, $S_2B_1P_1$ and $S_2B_2P_1$ recorded 0.32%. In pooled data, treatment combinations $S_2B_0P_0$, $S_2B_0P_1$, $S_2B_1P_0$, $S_2B_1P_1$ and $S_2B_2P_1$ recorded the highest S content of 0.32% in stover. The lowest S content in stover was obtained in control treatment $S_0B_0P_0$ which recorded 0.25% both during 2016 and 2017 and in pooled. The B content in stover was highest with treatment $S_2B_2P_1$ which recorded 2.09 mg kg^{-1} during 2016 and in 2017 $S_2B_2P_0$ recorded the highest B content of 2.14 mg kg^{-1} while in pooled $S_2B_2P_1$ was highest with 2.10 mg kg^{-1}. The lowest B content in stover was observed with the control treatment $S_0B_0P_0$ which recorded 0.90 mg kg^{-1} and 0.92 mg kg^{-1} during 2016 and 2017, respectively with a pooled value of 0.91 mg kg^{-1}. The various treatment combinations did not show any significant effect on the nutrient content in stover.

4.4.2. Effect on N, P, K, S and B content in seeds

4.4.2.1. Effect of sulphur on N, P, K, S and B content in seeds

The effect of sulphur on N, P, K, S and B content in seeds has been presented in Table 4.4.2 (a) and Fig. 5. The results revealed that successive increased in the levels of sulphur application had a significant effect on the N, P, K, S and B content in seeds. The highest N content was observed when S_2 was applied which recorded 6.34% both during 2016 and 2017 and in pooled whereas, the lowest N content in seeds was observed with control (S_0) which recorded 5.97% and 5.95%

Table 4.4.2 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on N, P, K, S and B content in seeds

Treatments	**N content (%)**			**P content (%)**			**K content (%)**			**S content (%)**			**B content (mg kg^{-1})**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	5.97	5.95	5.96	0.31	0.31	0.31	1.56	1.55	1.56	0.21	0.20	0.20	2.19	2.18	2.19
S_1	6.19	6.19	6.19	0.37	0.37	0.37	1.69	1.69	1.69	0.29	0.29	0.29	3.31	3.15	3.23
S_2	6.34	6.34	6.34	0.39	0.39	0.39	1.71	1.70	1.71	0.30	0.30	0.30	3.34	3.33	3.34
SEm±	***0.014***	***0.018***	***0.012***	***0.002***	***0.003***	***0.002***	***0.008***	***0.004***	***0.005***	***0.002***	***0.003***	***0.002***	***0.009***	***0.007***	***0.006***
CD(P=0.05)	***0.055***	***0.072***	***0.038***	***0.009***	***0.013***	***0.006***	***0.031***	***0.017***	***0.015***	***0.006***	***0.012***	***0.006***	***0.035***	***0.029***	***0.019***
B_0	6.12	6.11	6.12	0.35	0.34	0.34	1.62	1.61	1.62	0.25	0.25	0.25	2.65	2.56	2.61
B_1	6.18	6.18	6.18	0.36	0.36	0.36	1.66	1.66	1.66	0.27	0.27	0.27	2.95	2.91	2.93
B_2	6.21	6.19	6.20	0.36	0.36	0.36	1.69	1.66	1.68	0.28	0.28	0.28	3.24	3.20	3.22
SEm±	***0.010***	***0.011***	***0.008***	***0.001***	***0.002***	***0.001***	***0.007***	***0.004***	***0.004***	***0.002***	***0.002***	***0.002***	***0.007***	***0.010***	***0.006***
CD(P=0.05)	***0.032***	***0.035***	***0.022***	***0.003***	***0.007***	***0.004***	***0.020***	***0.013***	***0.011***	***0.006***	***0.007***	***0.004***	***0.023***	***0.030***	***0.018***
P_0	6.15	6.14	6.15	0.35	0.35	0.35	1.65	1.64	1.65	0.26	0.26	0.26	2.90	2.87	2.88
P_1	6.19	6.18	6.18	0.36	0.36	0.36	1.66	1.65	1.66	0.27	0.27	0.27	3.00	2.91	2.95
SEm±	***0.006***	***0.010***	***0.006***	***0.002***	***0.002***	***0.001***	***0.007***	***0.006***	***0.004***	***0.002***	***0.003***	***0.002***	***0.009***	***0.008***	***0.006***
CD(P=0.05)	***0.018***	***0.031***	***0.017***	***0.006***	***0.005***	***0.004***	***0.020***	***0.018***	***0.013***	***0.007***	***0.008***	***0.005***	***0.026***	***0.024***	***0.017***

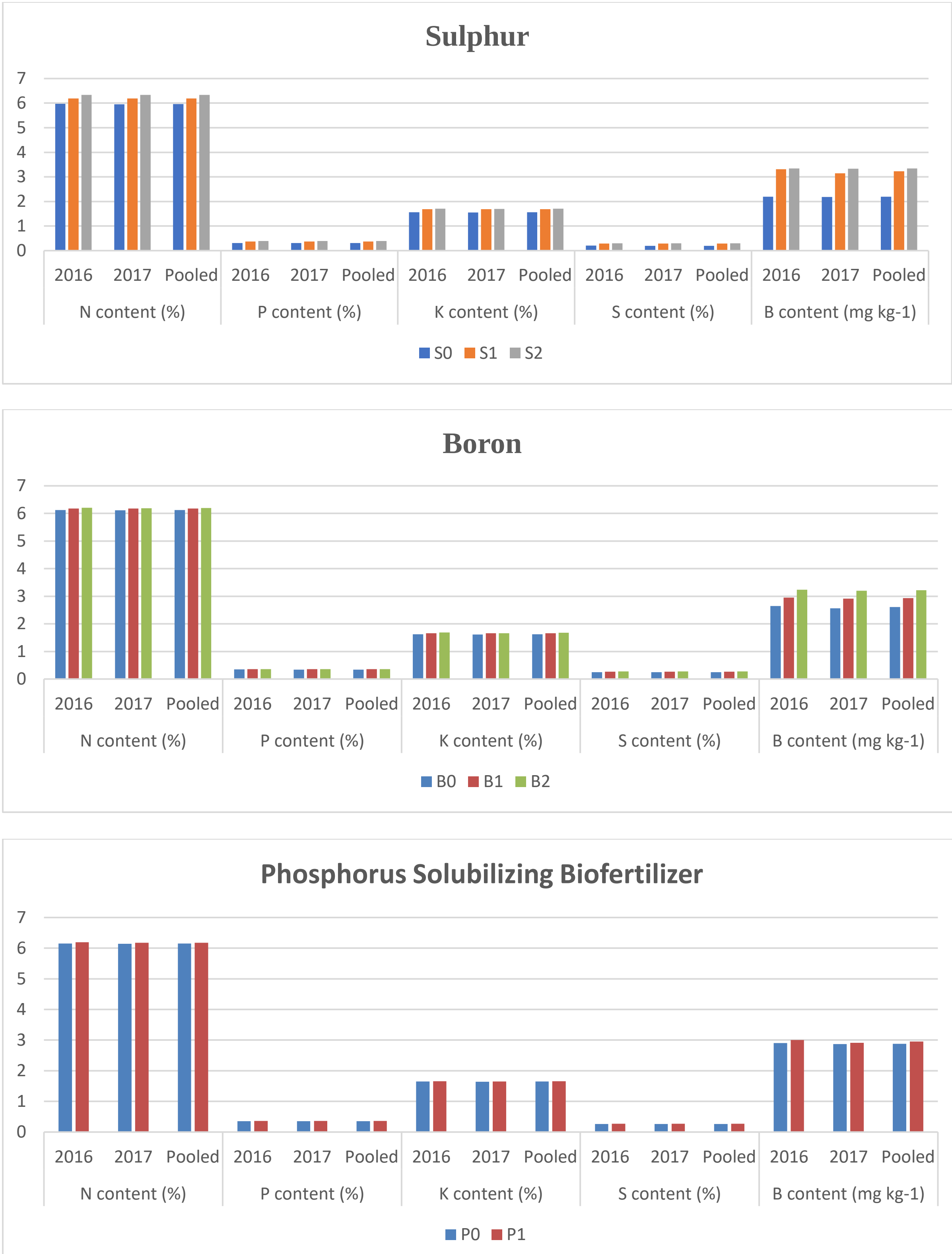


Fig.7: Effect of sulfur, boron and phosphorus solubilizing biofertilizeron N, P, K, S and B content in seeds

during 2016 and 2017 with a pooled value of 5.96%. The highest P content in seeds was observed with S_2 which recorded 0.39% both during 2016 and 2017 and in the pooled data while the lowest P content in seeds observed in the control treatment (S_0) with 0.31% both during 2016 and 2017 and in pooled. The results revealed that highest K content in seeds of 1.71% and 1.70% during 2016 and 2017, respectively with S_2 *i.e.*, application 40 kg S ha^{-1}. The pooled data revealed that S_2 recorded the highest K content of 1.71% in seeds. The lowest K content in seeds of 1.56% and 1.55 was observed with S_0 level of sulphur application during 2016 and 2017, respectively with pooled value of 1.56%. There was slight increased in the S content in the stover with increasing level of sulphur application. The highest S content in stover was recorded when S_2 level of sulphur was applied which recorded 0.30% both in 2016 and 2017 and in the pooled. The lowest S content was observed when no sulphur was applied *i.e.*, S_0 which recorded 0.21% and 0.20% during 2016 and 2017, respectively with a pooled value of 0.20%. The nutrient B content in seeds was also found to increase with increased level of sulphur application and the highest B content in seeds was observed with S_2 which recorded 3.34 mg kg^{-1} and 3.33 mg kg^{-1} during 2016 and 2017, respectively, with a pooled value of 3.34 mg kg^{-1}. The lowest B content was observed with control treatment S_0 with a value of 2.19 mg kg^{-1} and 2.18 mg kg^{-1} during 2016 and 2017, respectively with a pooled data 2.19 mg kg^{-1}.

The results are in agreement with the findings of Majumdar *et al.* (2001) and Najar *et al.* (2011) who reported that the nutrient N, P and S content in soybean seeds was significantly increased with sulphur fertilization. Biswas *et al.* (2006) also observed that application of sulphur increases the N, K, S and B content in soybean significantly. The increase in effective number and size of root nodules facilitating better N_2 fixation could have attributed to increased N content in steeds (Ganeshamurthy and Reddy, 2000). The S fertilization might have favourable effect on adsorption of other elements by the plants leading to significant increase in P content in seeds. Patel and Zinzala (2018) observed positive impact on K uptake by soybean through sulphur application thereby increasing the K content in the stover. The significant increased in S content in seeds could be attributed to application of adequate amount of sulphur resulting in enhanced absorption and translocation of sulphur by the plants (Shrivastava *et al.*, 2000). Sulphur fertilization must have contributed to improved root growth thereby increasing the uptake of B by the plants and its content in the seeds in soybean.

4.4.2.2. Effect of boron on N, P, K, S and B content in seeds

The results on the effect of boron on the N, P, K, S and B content tin seeds has been presented in Table 4.4.2 (a) and Fig. 7. The observations revealed that increasing the level of boron application significantly influence the N, P, K, S and B content tin seeds. The highest N content in seeds was observed with B_2 which recorded 6.21% and 6.19% during 2016 and 2017, respectively with a pooled value of 6.20% while the lowest was observed in control (B_0) which recorded 6.12 and 6.11% with a pooled value of 6.12% during 2016 and 2017, respectively. The P content in seeds was highest when B_1 and B_2 were applied where both recorded 0.36% both during 2016 and 2017 and in pooled. The lowest P content in seeds was observed with control treatment B_0 which recorded 0.35% and 0.34% during 2016 and 2017 respectively with a pooled value of 0.34%. The effect of treatment B_1 and B_2 on B content in seeds were found to be statistically at par with each other. The K content in seeds was highest when treatment S_2 was applied during 2016 which recorded 1.69% while both S_1 and S_2 recorded the same K content of 1.66% indicating they were at par during 2017. The pooled data revealed that treatment B_2 which recorded a K content of 1.68% in seeds. The lowest K content in seeds were observed where no boron was applied *i.e.*, B_0 which recorded 1.62% and 1.61% with a pooled value of 1.62% during 2016 and 2017, respectively. The highest S content in seeds was observed with treatment B_2 which recorded 0.28% in both the years and in pooled while B_0 (control) recorded the least B content in seeds with 0.25% both during 2016 and 2017 and in the pooled. It was observed that increasing the level of boron application increases the B content in the seeds. The highest B content was observed with B_2 which obtained 3.24 mg kg^{-1} and 3.20 mg kg^{-1} during 2017 and 2017, respectively with a pooled value of 3.22 mg kg^{-1}. The least B content in seeds was observed in control (B_0) which recorded 2.65 mg kg^{-1} and 2.56 mg kg^{-1} during 2016 and 2017, respectively with a pooled value of 2.61 mg kg^{-1}.

The present findings are in accordance with the observations of Patel and Zinzala (2018) who also observed that boron application contributes to significant increase in N, P, K, S and B content in plants.The significant increased N content in seeds could be attributed to the favourable effect of boron application on root nodulation and improved N_2 fixation thereby increasing the N content in the stover (Patel and Zinzala, 2018). Significantly higher content of P and K in seeds with boron application might be due to its positive effect on absorption of nutrients by the plants from the soil with improved plant growth rate and its translocation into the seeds through balanced plant nutrition. Boron deficiency is often encountered under acidic soil and its application might have enhanced its availability and increased root activity resulting in higher nutrient uptake by the plants which contributed to the significant increase in the content of S and B in the seeds.

4.4.2.3. Effect of phosphorus solubilizing biofertilizer on N, P, K, S and B content in seeds

The effect of phosphorus solubilizing biofertilizer on N, P, K, S and B content in seeds has been shown in Table 4.4.2 (a) and Fig. 7. The results revealed that seed inoculation with phosphorus solubilizing biofertilizer significantly influence the N, P, K, S and B content in seeds. Higher N content in seeds was observed when P_1 was applied which recorded N content of 6.19% and 6.18% in 2016 and 2017, respectively with a pooled value of 6.18% while P_0 recorded lower N content in seeds with 6.15% and 6.14% during 2016 and 2017, respectively with pooled value of 6.15%. The P content was observed to be higher when P_1 was applied which recorded 0.36% in both years and in pooled while P_0 recorded lower P content of 0.35% both in 2016 and 2017 and in the pooled data. The K content in seeds with treatment P_1 recorded 1.66% and 1.65% during 2016 and 2017, respectively while P_0 recorded slightly lower K content in seeds of 1.65% and 1.64% during 2016 and 2017, respectively. In the pooled data, both P_0 and P_1 recorded K content of 1.65% and 1.66% respectively. Similarly higher S content was observed with P_1 which recorded 0.27% both in 2016 and 2017, respectively and in pooled while P_0 recorded lower S content in seeds with 4.50% and 4.45% during 2016 and 2017, respectively with pooled value of 4.48%. The B content in seeds was found to increase when the seeds were inoculated with phosphorus solubilizing biofertilizer (P_1) which recorded 3.00 mg kg^{-1} and 2.91 mg kg^{-1} during 2016 and 2017, respectively with pooled value of 2.95 mg kg^{-1}. The B content was found to be lower in uninoculated seeds (P_0) which recorded 2.90 mg kg^{-1} and 2.87 mg kg^{-1} with a pooled value of 2.88 mg kg^{-1} during 2016 and 2017, respectively.

Phosphorus deficiency is a major constraint under acidic soil condition due to phosphate fixation. As such application of phosphorus solubilizing biofertilizer might have solubilized the insoluble phosphate present in the soil thereby increasing its availability to the plants. Improved root growth and activity with enhanced phosphorus availability facilitates higher uptake of nutrients from the soil and the translocation of the nutrients into different parts of the plant could have contributed to the significant increase in the N, P, K, S and B content in the seeds. Sandeep *et al.* (2008) observed higher uptake of nutrients by soybean with application of phosphate solubilizing microorganisms (PSM) thereby increasing their concentration on the plants.

4.4.2.4. Effect of sulphur and boron interaction on N, P, K, S and B content in seeds

Table 4.4.2 (b) showed the results on the effect of sulphur and boron interaction on N, P, K, S and B content in seeds. The results revealed that the interaction between sulphur and boron did not have any significant effect on the N, P, K, and S content in seeds. The highest N content was obtained from treatment S_2B_2 which recorded 6.37% during 2016 and S_2B_2 with 6.37% in 2017 while in pooled S_2B_2 recorded the highest N content of 6.37%. The lowest N content in seeds was observed with S_0B_0 which recorded 5.95% and 5.94% during 2016 and 2017, respectively with a pooled of 6.37%. The P content in seeds was the maximum when S_2B_1 was applied which obtained 0.40% during 2016 and in 2017 S_2B_1 and S_2B_2 recorded the same P content of 0.39% while in pooled S_2B_0, S_2B_1 and S_2B_2 all recorded the same value of 0.39%. The lowest P content in seeds was obtained from the control (S_0B_0) which recorded 0.29% in both the years and in pooled. The interaction effects revealed that S_2B_1 and S_2B_2 recorded the highest K content of 1.73% during 2016 while S_2B_2 was highest with a value of 1.72% in 2017. In the pooled data, treatment S_2B_2 recorded highest K content of 1.73% in seeds. The lowest K content in seeds was observed with treatment S_0B_0 which recorded

Table 4.4.2 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on N, P, K, S and B content in seeds

Treatments	N content (%)			P content (%)			K content (%)			S content (%)			B content (mg kg^{-1})		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
S_0B_0	5.95	5.94	5.94	0.29	0.29	0.29	1.52	1.51	1.52	0.18	0.17	0.17	1.56	1.60	1.58
S_0B_1	5.96	5.96	5.96	0.30	0.31	0.30	1.56	1.56	1.56	0.21	0.20	0.20	2.15	2.15	2.15
S_0B_2	6.00	5.97	5.98	0.33	0.32	0.33	1.68	1.67	1.67	0.23	0.23	0.23	2.86	2.79	2.83
S_1B_0	6.11	6.11	6.11	0.36	0.35	0.35	1.69	1.71	1.70	0.28	0.27	0.27	3.06	2.86	2.96
S_1B_1	6.22	6.22	6.22	0.38	0.37	0.38	1.71	1.71	1.71	0.30	0.29	0.30	3.33	3.16	3.24
S_1B_2	6.26	6.24	6.25	0.38	0.37	0.38	1.66	1.66	1.66	0.31	0.30	0.30	3.54	3.42	3.48
S_2B_0	6.29	6.30	6.30	0.39	0.38	0.39	1.62	1.57	1.59	0.31	0.30	0.31	3.35	3.21	3.28
S_2B_1	6.35	6.37	6.36	0.40	0.39	0.39	1.73	1.70	1.72	0.30	0.30	0.30	3.36	3.42	3.39
S_2B_2	6.37	6.36	6.37	0.39	0.39	0.39	1.73	1.72	1.73	0.30	0.30	0.30	3.32	3.37	3.35
SEm±	***0.018***	***0.020***	***0.013***	***0.002***	***0.004***	***0.002***	***0.011***	***0.007***	***0.007***	***0.004***	***0.004***	***0.003***	***0.013***	***0.017***	***0.010***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***0.039***	***0.051***	***0.031***
S_0P_0	5.95	5.94	5.95	0.30	0.30	0.30	1.57	1.53	1.55	0.20	0.19	0.19	2.06	2.10	2.08
S_0P_1	5.98	5.96	5.97	0.31	0.31	0.31	1.56	1.56	1.56	0.21	0.21	0.21	2.32	2.27	2.29
S_1P_0	6.17	6.14	6.16	0.36	0.36	0.36	1.68	1.68	1.68	0.29	0.28	0.29	3.29	3.12	3.21
S_1P_1	6.22	6.24	6.23	0.38	0.37	0.38	1.71	1.69	1.70	0.30	0.29	0.30	3.33	3.17	3.25
S_2P_0	6.33	6.34	6.33	0.39	0.39	0.39	1.71	1.69	1.70	0.30	0.30	0.30	3.35	3.38	3.36
S_2P_1	6.35	6.35	6.35	0.39	0.39	0.39	1.71	1.71	1.71	0.30	0.30	0.30	3.34	3.29	3.31
SEm±	***0.011***	***0.018***	***0.010***	***0.004***	***0.003***	***0.002***	***0.012***	***0.010***	***0.008***	***0.004***	***0.005***	***0.003***	***0.015***	***0.014***	***0.010***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
B_0P_0	6.09	6.09	6.09	0.34	0.34	0.34	1.62	1.60	1.61	0.25	0.24	0.25	2.62	2.54	2.58
B_0P_1	6.14	6.14	6.14	0.35	0.35	0.35	1.62	1.63	1.63	0.26	0.25	0.25	2.68	2.58	2.63
B_1P_0	6.17	6.16	6.16	0.35	0.35	0.35	1.66	1.66	1.66	0.26	0.26	0.26	2.88	2.87	2.88
B_1P_1	6.19	6.21	6.20	0.36	0.36	0.36	1.67	1.67	1.67	0.27	0.27	0.27	3.01	2.94	2.98
B_2P_0	6.19	6.18	6.18	0.36	0.36	0.36	1.68	1.66	1.67	0.27	0.27	0.27	3.19	3.19	3.19
B_2P_1	6.23	6.20	6.22	0.37	0.36	0.37	1.69	1.67	1.68	0.28	0.28	0.28	3.29	3.20	3.25
SEm±	***0.011***	***0.018***	***0.010***	***0.004***	***0.003***	***0.002***	***0.012***	***0.010***	***0.008***	***0.004***	***0.005***	***0.003***	***0.015***	***0.014***	***0.010***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***

1.52% and 1.51% during 2016 and 2017, respectively with pooled value of 1.52%. The highest S content in seeds was observed with treatment S_1B_2 and S_2B_0 where both treatments recorded 0.31% during 2016 while during 2017 treatment combination S_1B_2, S_2B_0, S_2B_1 and S_2B_2 recorded the highest S content of 0.30%. In the pooled data, S_2B_0 recorded the highest S content of 0.31% in seeds.

The results revealed that sulphur and boron had a significant interaction effect on B content in seeds. The B content in seeds was highest with treatment S_1B_2 which recorded 3.54 mg kg^{-1} during 2016 and in 2017 treatment S_1B_2 and S_2B_1 observed the highest B content of 3.42 mg kg^{-1} while in pooled S_1B_2 was highest with 3.48 mg kg^{-1}. The lowest B content was observed where no S and B were applied *i.e.*, S_0B_0 which recorded 1.56 mg kg^{-1} and 1.60 mg kg^{-1} during 2016 and 2017, respectively with a pooled value of 1.58 mg kg^{-1}.

Ganie *et al.* (2014) observed synergistic interaction effect between sulphur and boron which contributes to significant increase in B content in seeds.

4.4.2.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B content in seeds

The results on the effect of sulphur and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B content in seeds has been presented in Table 4.4.2 (b). It was observed that the interaction between sulphur and phosphorus solubilizing biofertilizer did not have any significant effect on the N, P, K, S and B content in seeds. The highest N content of 6.35% was observed with S_2P_1 both the years and in pooled while S_0P_0 recorded lowest N content of 5.95% and 5.94% with a pooled of 5.95% during 2016 and 2017, respectively. The P content in seeds was highest with treatment S_2P_0 and S_2P_1 where both recorded 0.39% in 2016 and 2017 and in pooled. The lowest P content was observed in the control treatment S_0P_0 with 0.30% both during 2016 and 2017 and in the pooled. The highest K content in seeds was observed with treatment S_1P_1, S_2P_0 and S_2P_1 where all the treatment recorded 1.71% during 2016 while S_2P_1 obtained the highest K content of 1.71% during 2017. In the pooled data treatment S_2P_1 recorded the highest K content of 1.71%. The lowest K content was observed in treatment S_0P_1 with a value of 1.56% during 2016 while in 2017 S_0P_0 was lowest with 1.53% K content in seeds. In the pooled data, the lowest K content in seeds was observed with the control treatment S_0P_0 with a value of 1.55%. The S content in seeds was highest with treatment S_1P_1, S_2P_0 and S_2P_1 during 2016 where all recorded 0.30% and in 2017 S_2P_0 and S_2P_1 recorded the highest S content in seeds with 0.30%. In the pooled data, S_1P_1, S_2P_0 and S_2P_1 recorded the highest S content of 0.30% in seeds. The lowest S content in seeds was observed with S_0P_0 which recorded 0.20% and 0.19% with a pooled of 0.19% during 2016 and 2017, respectively. The highest B content in seeds was obtained with treatment S_2P_0 having 3.35 mg kg^{-1} and 3.38 mg kg^{-1} with a pooled value of 3.36 mg kg^{-1} during 2016 and 2017, respectively. The lowest S content in seeds was observed with control treatment S_0P_0 having 2.06 mg kg^{-1} and 2.10 mg kg^{-1} with a pooled value of 2.08 mg kg^{-1} during 2016 and 2017, respectively.

4.4.2.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B content in seeds

The results on the effect of boron and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B content in seeds has been shown on Table 4.4.2 (b). It was evident from the results obtained that the interaction between boron and phosphorus solubilizing biofertilizer was non significant. The results revealed that application of treatment B_2P_1 obtained the highest N content in seeds with 6.23% and 6.20% with a pooled value of 6.22% during 2016 and 2017, respectively. The lowest N content in seeds was observed in the control treatment B_0P_0 with 6.09% in both 2016 and 2017 and in the pooled. The P content in seeds was highest where treatment B_2P_1 was applied which recorded 0.37% during 2016 while during 2017 treament combination B_1P_1, B_2P_0 and B_2P_1 all recorded the same value of 0.36%. In the pooled table, treatment B_2P_1 obtained the highest P content of 0.37% in seeds. The highest K content in seeds was obtained from treatment B_2P_1 which recorded 1.69% during 2016 while in 2017 it was observed with treatment B_1P_1 and B_2P_1 where both recorded 1.67%. The pooled data revealed that B_2P_1 recorded the highest K content of 1.68% in seeds.The lowest K content were observed with treatment B_0P_0 and B_0P_1 with the same value of 1.62% during 2016 while in 2017 B_0P_0 recorded 1.60%. The pooled data revealed that B_0P_0 recorded the lowest K content of 1.61% in seeds. The S content in seeds was highest where treatment B_2P_1 was applied which recorded 0.28% both during 2016 and 2017 and in the pooled data. The lowest S content in seeds was recorded in the control plot B_0P_0 which recorded 0.25% and 0.24% during 2016 and 2017 with a pooled value of 0.25%, respectively. The highest B content in seeds was observed when treatment B_2P_1 was applied which obtained 3.29 mg kg^{-1} and 3.20 mg kg^{-1} during 2016 and 2017 with a pooled data of 3.25 mg kg^{-1}, respectively. The lowest B content in seeds was obtained from the controlled treatment B_0P_0 which recorded 2.62 mg kg^{-1} and 2.54 mg kg^{-1} during 2016 and 2017 with a pooled value of 2.58 mg kg^{-1}, respectively.

4.4.2.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B content in seeds

The results on the effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction N, P, K, S and B content in soybean seeds has been presented in Table 4.4.2 (c). The results revealed that the different treatment

Table 4.4.2 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on N, P, K, S and B content in seeds

Treatments	**N content (%)**			**P content (%)**			**K content (%)**			**S content (%)**			**B content (mg kg^{-1})**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
$S_0B_0P_0$	5.94	5.92	5.93	0.29	0.29	0.29	1.51	1.48	1.50	0.17	0.16	0.17	1.47	1.53	1.50
$S_0B_0P_1$	5.96	5.95	5.95	0.29	0.30	0.30	1.52	1.55	1.53	0.18	0.18	0.18	1.64	1.67	1.66
$S_0B_1P_0$	5.96	5.95	5.95	0.29	0.30	0.30	1.55	1.56	1.55	0.20	0.19	0.20	2.04	2.08	2.06
$S_0B_1P_1$	5.97	5.97	5.97	0.31	0.31	0.31	1.57	1.56	1.57	0.21	0.21	0.21	2.27	2.22	2.24
$S_0B_2P_0$	5.97	5.96	5.97	0.32	0.32	0.32	1.61	1.56	1.59	0.22	0.22	0.22	2.66	2.68	2.67
$S_0B_2P_1$	6.03	5.97	6.00	0.34	0.33	0.33	1.65	1.62	1.64	0.24	0.25	0.25	3.06	2.91	2.98
$S_1B_0P_0$	6.06	6.06	6.06	0.35	0.34	0.34	1.62	1.58	1.60	0.27	0.27	0.27	3.04	2.85	2.94
$S_1B_0P_1$	6.16	6.15	6.16	0.36	0.37	0.37	1.66	1.65	1.65	0.28	0.27	0.28	3.08	2.87	2.97
$S_1B_1P_0$	6.21	6.16	6.18	0.38	0.37	0.37	1.68	1.69	1.68	0.29	0.28	0.29	3.28	3.07	3.18
$S_1B_1P_1$	6.23	6.29	6.26	0.38	0.38	0.38	1.70	1.69	1.69	0.31	0.30	0.31	3.38	3.24	3.31
$S_1B_2P_0$	6.23	6.21	6.22	0.37	0.37	0.37	1.72	1.70	1.71	0.30	0.30	0.30	3.55	3.45	3.50
$S_1B_2P_1$	6.28	6.28	6.28	0.39	0.37	0.38	1.68	1.71	1.70	0.31	0.30	0.30	3.54	3.40	3.47
$S_2B_0P_0$	6.28	6.29	6.28	0.39	0.38	0.39	1.70	1.70	1.70	0.31	0.31	0.31	3.37	3.23	3.30
$S_2B_0P_1$	6.31	6.31	6.31	0.40	0.38	0.39	1.71	1.69	1.70	0.31	0.30	0.30	3.33	3.19	3.26
$S_2B_1P_0$	6.34	6.36	6.35	0.39	0.39	0.39	1.74	1.70	1.72	0.30	0.31	0.30	3.32	3.46	3.39
$S_2B_1P_1$	6.36	6.37	6.37	0.40	0.39	0.40	1.72	1.73	1.73	0.30	0.30	0.30	3.40	3.37	3.38
$S_2B_2P_0$	6.36	6.36	6.36	0.39	0.39	0.39	1.72	1.74	1.73	0.29	0.30	0.29	3.35	3.44	3.40
$S_2B_2P_1$	6.38	6.37	6.38	0.38	0.38	0.38	1.75	1.71	1.73	0.30	0.30	0.30	3.29	3.30	3.30
SEm±	***0.018***	***0.031***	***0.018***	***0.006***	***0.005***	***0.004***	***0.020***	***0.018***	***0.013***	***0.007***	***0.009***	***0.005***	***0.027***	***0.024***	***0.018***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***0.079***	***0.073***	***0.052***

interaction does not have any significant effect on the N, P, K, and S content in seeds with exception B content which was observed to be significant. The results revealed that the lowest N content in seeds was observed in the control plot $S_0B_0P_0$ which recorded 5.94% and 5.92% during 2016 and 2017 with pooled value of 5.93%, respectively while $S_2B_2P_1$ recorded the highest N content of 6.38% and 6.37% during 2016 and 2017, respectively, with pooled value of 6.38%. It was observed that during 2016 treatment $S_2B_0P_1$ and $S_2B_1P_1$ recorded the highest P content in seeds with 0.40% while in 2017 treatment $S_2B_1P_0$, $S_2B_0P_1$, $S_2B_1P_1$ and $S_2B_2P_0$ recorded the highest P content of 0.39%. From the pooled data, it was clear that treatment $S_2B_1P_1$ obtained the highest P content in seeds with a value of 0.40%. The lowest P content was observed in treatment $S_0B_0P_0$, $S_0B_0P_1$ and $S_0B_1P_0$ each recorded the same value of 0.29% while in 2017 $S_0B_0P_0$ recorded the lowest with same value of 0.29%. The pooled data revealed that the control treatment $S_0B_0P_0$ recorded the lowest with a value of 0.29% P content in seeds. The results of the overall interaction effects revealed that K content was highest with treatment $S_2B_2P_1$ which recorded 1.75% during 2016 while in 2017 $S_2B_2P_0$ was highest with a value of 1.74%. In the pooled data the highest K content in seeds were obtained from $S_2B_1P_1$, $S_2B_2P_0$ and $S_2B_2P_1$ where all three recorded 1.73%. From the data, it was clear that the lowest K content in seeds was observed in control treatment $S_0B_0P_0$ which recorded 1.51% and 1.48% during 2016 and 2017, respectively with pooled value of 1.50%. The results revealed that treatment $S_1B_1P_1$, $S_1B_2P_1$, $S_2B_0P_0$ and $S_2B_0P_1$ recorded the highest S content of 0.31% each during 2016 while in 2017 treatment $S_2B_0P_0$ and $S_2B_1P_0$ was highest with 0.31%. The pooled data revealed treatment $S_1B_1P_1$ and $S_1B_2P_1$ was highest with a S content of 0.31%. The lowest S content in seeds was obtained from control treatment $S_0B_0P_0$ which was 0.17% and 0.16% during 2016 and 2017, respectively with a pooled value of 0.17%.

The B content in seeds was found to be significantly influenced by the interaction between sulphur, boron and phosphorus solubilizing biofertilizer. It has been revealed that increasing the level of boron application alone or combination with sulphur and phosphorus solubilizing biofertilizer increases the boron concentration in seeds. The highest B content was recorded with treatment $S_1B_2P_0$ which was 3.55 mg kg^{-1} and 3.45 mg kg^{-1} during 2016 and 2017, respectively with a pooled data of 3.50 mg kg^{-1}. On the other hand, the lowest B content in seeds was recorded with control treatment $S_0B_0P_0$ which was 1.47 mg kg^{-1} and 1.50 mg kg^{-1} during 2016 and 2017 respectively with a pooled value of 1.50 mg kg^{-1}.

The increased in significant B content in seeds could be attributed to the increased boron availability through micronutrient boron application in combination secondary nutrient sulphur and phosphorus solubilizing biofertilizer which solubilzes the insoluble inorganic phosphate in the soil creating an optimum condition for vigorous plant growth. The improved plant growth through enhanced plant nutrient availability facilitates higher uptake of nutrients from the soil and later its accumulation in the seeds. The improvement in the uptake of nutrients due to higher dry matter production, seed and haulm yield (Chaithra and Hebsur, 2018) could have led to the increased content of B in seeds.

4.4.3. Effect on N, P, K, S and B uptake by stover

4.4.3.1. Effect of sulphur on N, P, K, S and B uptake by stover

The results on the effect of sulphur on N, P, K, S and B uptake by stover has been presented on Table 4.4.3 (a). The highest uptake of N, P, K, S and B was observed with application of S_2 (40 kg S ha^{-1}) which recorded 64.39 kg ha^{-1} and 65.01 kg ha^{-1}, 9.36 kg ha^{-1} and 9.25 kg ha^{-1}, 65.81 kg ha^{-1} and 65.98 kg ha^{-1}, 9.53 kg ha^{-1} and 9.56 kg ha^{-1}, and 61.02 g ha^{-1} and 61.75 g ha^{-1}, respectively during 2016

Table 4.4.3 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on N, P, K, S and B uptake by stover

Treatments	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})			S uptake (kg ha^{-1})			B uptake (g ha^{-1})		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	47.43	48.37	47.90	6.15	6.17	6.16	50.17	50.51	50.34	7.23	7.09	7.16	30.26	30.12	30.19
S_1	51.36	53.12	52.24	7.79	8.07	7.93	58.31	58.34	58.33	8.35	8.50	8.42	48.65	48.18	48.41
S_2	64.39	65.63	65.01	9.36	9.25	9.31	65.81	65.98	65.90	9.53	9.56	9.55	61.02	61.75	61.38
SEm±	***0.14***	***0.20***	***0.12***	***0.06***	***0.04***	***0.03***	***0.20***	***0.13***	***0.12***	***0.017***	***0.010***	***0.010***	***0.04***	***0.06***	***0.04***
CD(P=0.05)	***0.54***	***0.77***	***0.39***	***0.22***	***0.14***	***0.11***	***0.78***	***0.51***	***0.39***	***0.067***	***0.039***	***0.032***	***0.16***	***0.24***	***0.12***
B_0	51.59	52.96	52.28	7.07	7.27	7.17	55.74	55.89	55.81	7.92	7.92	7.92	41.36	41.12	41.24
B_1	54.17	55.70	54.94	7.93	7.86	7.90	58.07	58.20	58.13	8.43	8.40	8.42	46.93	47.10	47.01
B_2	57.41	58.46	57.93	8.30	8.35	8.32	60.49	60.75	60.62	8.76	8.83	8.80	51.64	51.83	51.74
SEm±	***0.15***	***0.13***	***0.10***	***0.06***	***0.03***	***0.03***	***0.12***	***0.07***	***0.07***	***0.012***	***0.019***	***0.011***	***0.06***	***0.07***	***0.05***
CD(P=0.05)	***0.45***	***0.39***	***0.28***	***0.19***	***0.09***	***0.10***	***0.37***	***0.20***	***0.20***	***0.036***	***0.059***	***0.033***	***0.19***	***0.21***	***0.13***
P_0	53.55	54.83	54.19	7.41	7.48	7.44	57.45	57.71	57.58	8.26	8.25	8.26	45.35	45.45	45.40
P_1	55.23	56.58	55.91	8.12	8.18	8.15	58.75	58.85	58.80	8.49	8.51	8.50	47.94	47.91	47.93
SEm±	***0.11***	***0.09***	***0.07***	***0.05***	***0.02***	***0.03***	***0.05***	***0.06***	***0.04***	***0.011***	***0.012***	***0.008***	***0.07***	***0.05***	***0.04***
CD(P=0.05)	***0.34***	***0.27***	***0.21***	***0.14***	***0.05***	***0.07***	***0.16***	***0.17***	***0.11***	***0.032***	***0.035***	***0.023***	***0.21***	***0.15***	***0.13***

and 2017 while in the pooled data it was 65.01 kg ha^{-1}, 9.31 kg ha^{-1}, 65.90 kg ha^{-1}, 9.55 kg ha^{-1} and 61.38 g ha^{-1}, respectively. The lowest uptake of N, P, K, S and B by stover has been observed with S_0 (0 kg S ha^{-1}) which recorded 47.43 kg ha^{-1} and 48.37 kg ha^{-1}, 6.15 kg ha^{-1} and 6.17 kg ha^{-1}, 50.17 kg ha^{-1} and 50.17 kg ha^{-1}, 7.23 kg ha^{-1} and 7.09 kg ha^{-1}, and 30.26 g ha^{-1} and 30.12 g ha^{-1} during 2016 and 2017, respectively, while in the pooled data, it was 47.90 kg ha^{-1}, 6.16 kg ha^{-1}, 50.34 kg ha^{-1}, 7.16 kg ha^{-1}, and 30.19 g ha^{-1}, respectively. It was observed that application of sulphur had a significant influence on nutrient uptake by stover. However, application of sulphur at the rate of 40 kg S ha^{-1} (S_2) was found to be significant over S_1 and S_0.

Najar *et al.* (2011) and Sharma *et al.* (2014) also reported that application of sulphur significantly increased the uptake of N, P, K and S by soybean. The increased in N uptake with S application might be due to role of sulphur in enhancing the enzyme activity responsible for reduction of nitrate in plants. The mobilization of P into available form by S might be responsible for the higher P uptake by plants (Sharma *et al.* 2014). Singh *et al.* (2001) opined that application of S stimulates the uptake of P and K by plants. The increased nutrient N, P, K, S and B uptake was also observed by Longkumer *et al.* (2017) with sulphur application, which might have been due to the improved nutrient availability and its adsorption by the roots.

4.4.3.2. Effect of boron on N, P, K, S and B uptake by stover

Table 4.4.3 (a) showed the result on the effect of boron on N, P, K, S and B uptake by stover. It was observed that application of boron up to 2 kg ha^{-1} had a significant influence on nutrient uptake by stover in soybean. The highest uptake of N, P, K, S and B by stover was observed with application of B_2 which recorded

57.41 kg ha^{-1} and 58.46 kg ha^{-1}, 8.30 kg ha^{-1} and 8.35 kg ha^{-1}, 60.49 kg ha^{-1} and 60.75 kg ha^{-1}, 8.76 kg ha^{-1} and 8.83 kg ha^{-1}, and 51.64 g ha^{-1} and 51.83 g ha^{-1} during 2016 and 2017, respectively. The lowest uptake of N, P, K, S and B uptake by stover has been observed with B_0 which recorded 51.59 kg ha^{-1} and 52.96 kg ha^{-1}, 7.07 kg ha^{-1} and 7.27 kg ha^{-1}, 55.74 kg ha^{-1} and 55.89 kg ha^{-1}, 7.92 kg ha^{-1} and 7.92 kg ha^{-1}, and 41.36 g ha^{-1} and 41.12 g ha^{-1} during 2016 and 2017, respectively.

In the pooled data, B_2 recorded an average mean N, P, K, S and B uptake by stover of 57.93 kg ha^{-1}, 8.32 kg ha^{-1}, 60.62 kg ha^{-1}, 8.80 kg ha^{-1} and 51.74 g ha^{-1} whereas B_0 recorded 52.28 kg ha^{-1}, 7.17 kg ha^{-1}, 55.81 kg ha^{-1}, 7.92 kg ha^{-1} and 41.24 g ha^{-1}, respectively. The uptake of N, P, K, S and B uptake by stover as influenced by B_2 was found to be significant over B_1 and B_0 in both the years.

Longkumer *et al.* (2017) and Chaithra *et al.* (2018) revealed that application of boron increases the uptake of N, P, K, S and B by soybean. Kundu *et al.* (2016) observed that application of 2.0 and 4.0 kg ha^{-1} boron recorded the highest uptake of S and B by sunflower and mustards. Rathod *et al.* (2016) opined that application of boron increases the uptake of B by soybean. The improvement in the uptake of nutrients could be attributed to higher dry matter production, seed and haulm yield (Chaithra and Hebsur, 2018).

4.4.3.3. Effect of phosphorus solubilizing biofertilizer on N, P, K, S and B uptake by stover

The effect of phosphorus solubilizing biofertilizer on N, P, K, S and B uptake by stover has been presented in Table 4.4.3 (a). The application of phosphorus solubilizing biofertilizer (P_1) recorded higher N, P, K, S and B uptake by stover with corresponding values of 55.23 kg ha^{-1} and 56.58 kg ha^{-1}, 8.12 kg ha^{-}

^{1} and 8.18 kg ha^{-1}, 58.75 kg ha^{-1} and 58.85 kg ha^{-1}, 8.49 kg ha^{-1} and 8.51 kg ha^{-1}, and 47.94 g ha^{-1} and 47.91 g ha^{-1} during 2016 and 2017, respectively, as compared to P_0 which recorded lower uptake with corresponding values of 53.55 kg ha^{-1} and 54.83 kg ha^{-1}, 7.41 kg ha^{-1} and 7.48 kg ha^{-1}, 57.45 kg ha^{-1} and 57.71 kg ha^{-1}, 8.26 kg ha^{-1} and 8.25 kg ha^{-1}, and 45.35 g ha^{-1} and 45.45 g ha^{-1} during 2016 and 2017, respectively.

In the pooled data, the uptake of N, P, K, S and B uptake by stover with P_1 recorded an average mean of 55.91 kg ha^{-1}, 8.18 kg ha^{-1}, 58.80 kg ha^{-1}, 8.50 kg ha^{-1} and 47.93 g ha^{-1} whereas P_0 recorded 54.19 kg ha^{-1}, 7.44 kg ha^{-1}, 57.58 kg ha^{-1}, 8.26 kg ha^{-1}, 45.40 g ha^{-1}, respectively.

The application of phosphorus solubilizing biofertilizer (P_1) has been found to have significant influence on nutrient N, P, K, S and B uptake by stover which could be due to solubilization of fixed phosphate in soil by the biofertilizer resulting in well developed root system and better utilization of nutrients from the soil. Sandeep *et al.* (2008) unveiled that inoculation with PSM significantly increased the uptake of N and P by stover. Dhage and Kachhave (2008) also revealed that the N, P and K content and uptake by straw were significantly higher with application of 100% RDF + *Rhizobium* + PSB. Son *et al.* (2006), Argaw (2012) and Devi *et al.* (2012) also reported that inoculation with PSB resulted in higher uptake of nutrients by soybean.

4.4.3.4. Effect of sulphur and boron interaction on N, P, K, S and B uptake by stover

The results on the interaction effects of sulphur and boron on N, P, K, S and B uptake by stover has been presented in Table 4.4.3 (b). It has been observed that application of boron up to 2 kg ha^{-1} increases the uptake of N, P, K, S and B by

Table 4.4.3 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on N, P, K, S and B uptake by stover

Treatments	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})			S uptake (kg ha^{-1})			B uptake (g ha^{-1})		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0B_0	46.36	47.35	46.85	5.40	5.55	5.48	48.61	48.88	48.74	6.43	6.35	6.39	22.88	22.74	22.81
S_0B_1	47.49	47.99	47.74	6.43	6.10	6.26	49.91	50.17	50.04	7.53	7.15	7.34	31.17	31.00	31.08
S_0B_2	48.44	49.77	49.10	6.61	6.87	6.74	52.00	52.49	52.25	7.75	7.76	7.75	36.73	36.62	36.68
S_1B_0	49.29	51.20	50.24	6.97	7.58	7.28	55.19	55.20	55.19	8.13	8.22	8.17	43.51	42.28	42.89
S_1B_1	50.78	52.77	51.77	7.79	8.20	7.99	58.58	58.72	58.65	8.26	8.46	8.36	48.90	48.75	48.83
S_1B_2	54.01	55.38	54.69	8.60	8.41	8.51	61.17	61.10	61.13	8.66	8.82	8.74	53.55	53.50	53.52
S_2B_0	59.13	60.34	59.73	8.84	8.69	8.76	63.41	63.59	63.50	9.20	9.20	9.20	57.67	58.35	58.01
S_2B_1	64.26	66.33	65.30	9.57	9.29	9.43	65.71	65.72	65.71	9.52	9.59	9.55	60.72	61.54	61.13
S_2B_2	69.79	70.22	70.01	9.69	9.77	9.73	68.31	68.64	68.48	9.88	9.90	9.89	64.65	65.35	65.00
SEm±	***0.25***	***0.22***	***0.17***	***0.11***	***0.05***	***0.06***	***0.21***	***0.11***	***0.12***	***0.020***	***0.033***	***0.019***	***0.11***	***0.12***	***0.08***
CD(P=0.05)	***0.78***	***0.67***	***0.49***	***0.34***	***0.16***	***0.18***	***0.64***	***0.35***	***0.35***	***0.062***	***0.102***	***0.057***	***0.32***	***0.36***	***0.23***
S_0P_0	47.15	48.01	47.58	5.59	5.77	5.68	49.73	50.14	49.94	7.05	6.88	6.97	28.83	29.06	28.94
S_0P_1	47.70	48.73	48.21	6.70	6.58	6.64	50.62	50.88	50.75	7.41	7.29	7.35	31.70	31.18	31.44
S_1P_0	50.36	51.98	51.17	7.57	7.74	7.66	57.61	57.61	57.61	8.28	8.40	8.34	47.13	46.59	46.86
S_1P_1	52.35	54.25	53.30	8.00	8.40	8.20	59.02	59.07	59.04	8.42	8.60	8.51	50.17	49.77	49.97
S_2P_0	63.13	64.51	63.82	9.06	8.92	8.99	65.00	65.38	65.19	9.44	9.47	9.46	60.08	60.71	60.39
S_2P_1	65.66	66.75	66.20	9.66	9.57	9.62	66.62	66.59	66.60	9.63	9.65	9.64	61.95	62.79	62.37
SEm±	***0.20***	***0.16***	***0.13***	***0.08***	***0.03***	***0.04***	***0.09***	***0.10***	***0.07***	***0.019***	***0.021***	***0.014***	***0.12***	***0.09***	***0.08***
CD(P=0.05)	***0.58***	***0.47***	***0.36***	***0.25***	***0.09***	***0.13***	***0.28***	***0.29***	***0.19***	***0.055***	***0.061***	***0.040***	***0.36***	***0.27***	***0.22***
B_0P_0	51.08	52.22	51.65	6.91	6.99	6.95	55.13	55.18	55.16	7.77	7.79	7.78	39.98	39.89	39.94
B_0P_1	52.10	53.70	52.90	7.23	7.56	7.39	56.34	56.59	56.47	8.07	8.05	8.06	42.73	42.36	42.54
B_1P_0	53.32	54.94	54.13	7.48	7.48	7.48	57.52	57.76	57.64	8.33	8.24	8.29	45.98	45.72	45.85
B_1P_1	55.02	56.45	55.74	8.37	8.24	8.31	58.61	58.64	58.63	8.54	8.56	8.55	47.88	48.47	48.18
B_2P_0	56.24	57.34	56.79	7.84	7.95	7.89	59.68	60.19	59.94	8.67	8.73	8.70	50.08	50.74	50.41
B_2P_1	58.58	59.57	59.08	8.76	8.75	8.75	61.30	61.30	61.30	8.86	8.92	8.89	53.21	52.91	53.06
SEm±	***0.20***	***0.16***	***0.13***	***0.08***	***0.03***	***0.04***	***0.09***	***0.10***	***0.07***	***0.019***	***0.021***	***0.014***	***0.12***	***0.09***	***0.08***
CD(P=0.05)	***0.58***	***0.47***	***0.36***	***0.25***	***0.09***	***0.13***	***0.28***	***0.29***	***0.19***	***0.055***	***0.061***	***0.040***	***0.36***	***0.27***	***0.22***

stover at all levels of sulphur application. The highest uptake of N, P, K, S and B by stover was observed with treatment S_2B_2 which recorded 69.79 kg ha^{-1} and 70.22 kg ha^{-1}, 9.69 kg ha^{-1} and 9.77 kg ha^{-1}, 68.31 kg ha^{-1} and 68.64 kg ha^{-1}, 9.88 kg ha^{-1} and 9.90 kg ha^{-1}, and 64.65 g ha^{1} and 65.35 g ha^{-1} during 2016 and 2017, respectively, while in the pooled data, it was 70.01 kg ha^{-1}, 9.73 kg ha^{-1}, 68.48 kg ha^{-1}, 9.89 kg ha^{-1} and 65.00 g ha^{-1}, respectively. The lowest uptake of N, P, K, S and B by stover was observed with S_0B_0 which recorded 46.36 kg ha^{-1} and 47.35 kg ha^{-1}, 5.40 kg ha^{-1} and 5.55 kg ha^{-1}, 48.61 kg ha^{-1} and 48.88 kg ha^{-1}, 6.43 kg ha^{-1} and 6.35 kg ha^{-1}, and 22.88 g ha^{-1} and 22.74 g ha^{-1} during 2016 and 2017 respectively, while in the pooled data, it recorded an average mean of 46.85 kg ha^{-1}, 5.48 kg ha^{-1}, 48.74 kg ha^{-1}, 6.39 kg ha^{-1} and 22.81 g ha^{-1}, respectively. All the treatment combinations showed significant interaction effect on N, P, K, S and B uptake by stover over the control treatment S_0B_0. However, the interaction effect of S_2B_2 was found to be significantly higher.

Ismail *et al.* (2013), Longkumer *et al.* (2017) and Ravi *et al.* (2017) also reported that combined application of sulphur and boron significantly increases the uptake of N, P, K, S and B by soybean. Sarker *et al*. (2002) and Devi *et al.* (2012) observed higher uptake of S and B by stover with application of sulphur and boron. Increased nutrient uptake might be due to improved nutrient availability with sulphur and boron fertilization resulting in better growth and higher seed and stover yield which actuate more nutrients absorption from the soil.

4.4.3.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B uptake by stover

Table 4.4.3 (b) presented the effect of sulphur and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B uptake by stover. It was observed that application increased level of sulphur up to 40 kg ha^{-1} along with phosphorus solubilizing biofertilizer significantly increases the nutrient uptake by stover as compared to application of sulphur alone. The highest N, P, K, S and B uptake by stover was observed with S_2P_1 which recorded 65.66 kg ha^{-1} and 66.75 kg ha^{-1}, 9.66 kg ha^{-1} and 9.57 kg ha^{-1}, 66.62 kg ha^{-1} and 66.59 kg ha^{-1}, 9.63 kg ha^{-1} and 9.65 kg ha^{-1}, and 61.95 g ha^{-1} and 62.79 g ha^{-1} during 2016 and 2017, respectively while in the pooled data it was 66.20 kg ha^{-1}, 9.62 kg ha^{-1}, 66.60 kg ha^{-1}, 9.64 kg ha^{-1} and 62.37 g ha^{-1}, respectively. The lowest N, P, K, S and B uptake by stover was observed with plots receiving treatment S_0P_0 which recorded 47.15 kg ha^{-1} and 48.01 kg ha^{-1}, 5.59 kg ha^{-1} and 5.77 kg ha^{-1}, 49.73 kg ha^{-1} and 50.14 kg ha^{-1}, 7.05 kg ha^{-1} and 6.88 kg ha^{-1}, and 28.83 g ha^{-1} and 29.06 g ha^{-1} during 2016 and 2017, respectively while in the pooled data it was 47.58 kg ha^{-1}, 5.68 kg ha^{-1}, 49.94 kg ha^{-1}, 6.97 kg ha^{-1} and 28.94 g ha^{-1}, respectively. There was significant difference among the different treatments on the uptake of N, P, K, S and B by stover. However, treatment S_2P_1 was observed to be significant over other treatment combinations including control.

Improved S availability with sulphur application and enhanced phosphate solubilization in soil by phosphorus solubilizing biofertilizer, which is essential for proper root development and nodulation and optimum vegetative growth, seed and stover yields might have facilitated higher nutrient absorption from the soil. The increased nutrient N, P, K, S and B uptake was also observed by Longkumer *et al.* (2017) with sulphur application, which might have been due to the improved nutrient availability and its adsorption by the roots. Similar results on P and S uptake by stover was also observed by Dhage *et al.* (2014) with application of phosphorus and sulphur. Majumdar *et al.* (2001) also observed that application of phosphorus and sulphur significantly increases the uptake of N, P and S by soybean. Son *et al.* (2006), Argaw (2012) and Devi *et al.* (2012) also reported that inoculation with PSB resulted in higher uptake of nutrients by soybean.

4.4.3.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B uptake by stover

The effect of boron and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B uptake by stover has been presented on Table 4.4.3 (b). It was observed that increasing the levels of boron along with phosphorus solubilizing biofertilizer application had a significant influence on the N, P, K, S and B uptake by stover as compared to application of boron alone. The maximum N, P, K, S and B uptake by stover was observed with B_2P_1 which recorded 58.58 kg ha^{-1} and 59.57 kg ha^{-1}, 8.76 kg ha^{-1} and 8.75 kg ha^{-1}, 61.30 kg ha^{-1} and 61.30 kg ha^{-1}, 8.86 kg ha^{-1} and 8.92 kg ha^{-1}, and 53.21 g ha^{-1} and 52.91 g ha^{-1} during 2016 and 2017, respectively, while in the pooled data it was 59.08 kg ha^{-1}, 8.75 kg ha^{-1}, 61.30 kg ha^{-1}, 8.89 kg ha^{-1} and 53.06 g ha^{-1}, respectively. The lowest N, P, K, S and B uptake by stover was observed with B_0P_0 (control) which recorded 51.08 kg ha^{-1} and 52.22 kg ha^{-1}, 6.91 kg ha^{-1} and 6.99 kg ha^{-1}, 55.13 kg ha^{-1} and 55.18 kg ha^{-1}, 7.77 kg ha^{-1} and 7.79 kg ha^{-1}, and 39.98 g ha^{-1} and 39.89 g ha^{-1} during 2016 and 2017, respectively, while in the pooled it was 51.65 kg ha^{-1}, 6.95 kg ha^{-1}, 55.16 kg ha^{-1}, 7.78 kg ha^{-1} and 39.94 g ha^{-1}, respectively. Treatment B_2P_1 was found to be significant over other treatment combinations including control.

Phosphorus and boron play a vital in root development in plants. Both phosphorus and boron are deficient in the experimental plot and its increased availability through boron fertilization along with phosphorus solubilizing biofertilizer inoculation might have helped in better root development and nodulations which exploit the soil nutrient reserved resulting in higher nutrient uptake. Sentimenla *et al.* (2012) revealed that N, P, K and B uptake by soybean was significantly increased with different levels of phosphorus and boron fertilization either alone or in combination. Longkumer *et al.* (2017) and Chaithra and Hebsur (2018) revealed that application of boron increases the uptake of N, P, K, S and B by soybean. Sandeep *et al.* (2008) unveiled that inoculation with PSM significantly increased the uptake of N and P by stover.

4.4.3.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B uptake by stover

The results on the effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B uptake by stover has been shown in Table 4.4.3 (c). The maximum N, P, K, S and B uptake by stover has been observed with $S_2B_2P_1$ which recorded 71.09 kg ha^{-1} and 70.90 kg ha^{-1}, 10.25 kg ha^{-1} and 10.18 kg ha^{-1}, 69.12 kg ha^{-1} and 69.38 kg ha^{-1}, 9.98 kg ha^{-1} and 10.00 kg ha^{-1}, and 65.75 g ha^{-1} and 66.17 g ha^{-1} during 2016 and 2017, respectively, while in the pooled data, it recorded 71.00 kg ha^{-1}, 10.22 kg ha^{-1}, 69.25 kg ha^{-1}, 9.99 kg ha^{-1} and 65.96 g ha^{-1}, respectively. The lowest N, P, K, S and B uptake by stover has been observed with $S_0B_0P_0$ (control) which recorded 46.12 kg ha^{-1} and 46.90 kg ha^{-1}, 5.14 kg ha^{-1} and 5.20 kg ha^{-1}, 48.50 kg ha^{-1} and 48.61 kg ha^{-1}, 6.15 kg ha^{-1} and 6.13 kg ha^{-1}, and 21.71 g ha^{-1} and 22.22 g ha^{-1} during 2016 and 2017, respectively, and the pooled data it recorded 46.51 kg ha^{-1}, 5.17 kg ha^{-1}, 48.56 kg ha^{-1}, 6.14 kg ha^{-1} and 21.97 g ha^{-1}, respectively. The different treatment combinations were found to have significant influence on N, P, K, S and B uptake by stover. However, the N, P, K, S and B uptake by stover as affected by treatment $S_2B_2P_1$ was significantly higher than other treatment combination.

Table 4.4.3 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on N, P, K, S and B uptake by stover

Treatments	**N uptake (kg ha^{-1})**			**P uptake (kg ha^{-1})**			**K uptake (kg ha^{-1})**			**S uptake (kg ha^{-1})**			**B uptake (g ha^{-1})**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
$S_0B_0P_0$	46.12	46.90	46.51	5.14	5.20	5.17	48.50	48.61	48.56	6.15	6.13	6.14	21.71	22.22	21.97
$S_0B_0P_1$	46.59	47.80	47.20	5.67	5.90	5.79	48.72	49.14	48.93	6.70	6.57	6.63	24.05	23.26	23.66
$S_0B_1P_0$	47.07	47.76	47.41	5.57	5.56	5.56	49.66	50.15	49.90	7.32	6.84	7.08	29.92	29.32	29.62
$S_0B_1P_1$	47.90	48.22	48.06	7.29	6.63	6.96	50.16	50.20	50.18	7.73	7.47	7.60	32.42	32.67	32.54
$S_0B_2P_0$	48.27	49.36	48.82	6.07	6.55	6.31	51.03	51.68	51.35	7.69	7.68	7.68	34.85	35.63	35.24
$S_0B_2P_1$	48.60	50.18	49.39	7.14	7.20	7.17	52.97	53.30	53.14	7.81	7.83	7.82	38.62	37.62	38.12
$S_1B_0P_0$	48.95	50.65	49.80	6.83	7.32	7.08	54.28	53.95	54.12	8.06	8.12	8.09	41.78	40.22	41.00
$S_1B_0P_1$	49.63	51.74	50.69	7.11	7.84	7.48	56.10	56.45	56.27	8.19	8.32	8.25	45.24	44.33	44.79
$S_1B_1P_0$	50.19	52.19	51.19	7.58	7.92	7.75	58.03	57.89	57.96	8.22	8.39	8.31	47.80	47.48	47.64
$S_1B_1P_1$	51.36	53.35	52.36	8.00	8.48	8.24	59.13	59.54	59.34	8.30	8.54	8.42	50.00	50.02	50.01
$S_1B_2P_0$	51.95	53.11	52.53	8.31	7.96	8.14	60.51	60.99	60.75	8.55	8.70	8.63	51.82	52.05	51.94
$S_1B_2P_1$	56.06	57.64	56.85	8.89	8.86	8.88	61.82	61.22	61.52	8.77	8.93	8.85	55.27	54.95	55.11
$S_2B_0P_0$	58.18	59.10	58.64	8.77	8.45	8.61	62.62	62.98	62.80	9.10	9.11	9.11	56.46	57.22	56.84
$S_2B_0P_1$	60.07	61.58	60.82	8.91	8.93	8.92	64.20	64.20	64.20	9.31	9.28	9.29	58.89	59.48	59.18
$S_2B_1P_0$	62.71	64.88	63.80	9.30	8.97	9.14	64.87	65.25	65.06	9.44	9.50	9.47	60.23	60.36	60.30
$S_2B_1P_1$	65.81	67.78	66.80	9.84	9.61	9.72	66.54	66.19	66.37	9.59	9.67	9.63	61.21	62.73	61.97
$S_2B_2P_0$	68.50	69.54	69.02	9.12	9.35	9.24	67.50	67.91	67.70	9.78	9.81	9.79	63.56	64.54	64.05
$S_2B_2P_1$	71.09	70.90	71.00	10.25	10.18	10.22	69.12	69.38	69.25	9.98	10.00	9.99	65.75	66.17	65.96
SEm±	***0.34***	***0.28***	***0.22***	***0.14***	***0.05***	***0.08***	***0.16***	***0.17***	***0.12***	***0.032***	***0.036***	***0.024***	***0.21***	***0.16***	***0.13***
CD(P=0.05)	***1.01***	***0.82***	***0.63***	***0.43***	***0.16***	***0.22***	***0.48***	***0.51***	***0.34***	***0.10***	***0.11***	***0.07***	***0.63***	***0.46***	***0.38***

The improved nutrient availability through sulphur and boron fertilization along with solubilizing biofertilizer inoculation might be responsible for the higher nutrient uptake by the plants. Ismail *et al.* (2013), Longkumer *et al.* (2017) and Ravi *et al.* (2017) also reported that combined application of sulphur and boron significantly increases the uptake of N, P, K, S and B by soybean. Son *et al.* (2006), Argaw (2012) and Devi *et al.* (2012) also reported that inoculation with PSB resulted in higher uptake of nutrients by soybean.

4.4.4. Effect on N, P, K, S and B uptake by seeds

4.4.4.1. Effect of sulphur on N, P, K, S and B uptake by seeds

Table 4.4.4 (a) showed the results on the effects of sulphur on N, P, K, S and B uptake by seeds. It was observed that application of sulphur up to 40 kg S ha^{-1} had a significant influence on nutrient uptake by seeds. The maximum N, P, K, S and B uptake by seeds has been observed with S_2 (40 kg S ha^{-1}) which recorded 124.43 kg ha^{-1} and 125.62 kg ha^{-1}, 7.68 kg ha^{-1} and 7.67 kg ha^{-1}, 30.66 kg ha^{-1} and 30.61 kg ha^{-1}, 5.95 kg ha^{-1} and 5.94 kg ha^{-1}, and 65.59 g ha^{-1} and 65.99 gha^{-1} during 2016 and 2017, respectively, while in the pooled data it recorded an average mean uptake of 125.03 kg ha^{-1}, 7.68 kg ha^{-1}, 30.63 kg ha^{-1}, 5.95 kg ha^{-1} and 65.79 g ha^{-1}, respectively. The lowest N, P, K, S and B uptake by seeds has been observed with S_0 (0 kg S ha^{-1}) which recorded 89.69 kg ha^{-1} and 89.35 kg ha^{-1}, 4.61 kg ha^{-1} and 4.63 kg ha^{-1}, 25.47 kg ha^{-1} and 25.43 kg ha^{-1}, 3.09 kg ha^{-1} and 3.03 kg ha^{-1}, and 33.17 g ha^{-1} and 33.02 gha^{-1} during 2016 and 2017, respectively, while in the pooled data it recorded an average mean uptake of 89.52 kg ha^{-1}, 4.62 kg ha^{-1}, 25.45 kg ha^{-1}, 3.06 kg ha^{-1} and 33.09 g ha^{-1}, respectively. There was significant difference between the different levels of sulphur application on N, P,

Table 4.4.4 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on N, P, K, S and B uptake by seeds

Treatments	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})			S uptake (kg ha^{-1})			B uptake (g ha^{-1})		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	89.69	89.35	89.52	4.61	4.63	4.62	25.47	25.43	25.45	3.09	3.03	3.06	33.17	33.02	33.09
S_1	101.11	102.69	101.90	6.06	6.07	6.07	27.83	28.01	27.92	4.80	4.79	4.80	54.14	52.31	53.22
S_2	124.43	125.62	125.03	7.68	7.67	7.68	30.66	30.61	30.63	5.95	5.94	5.95	65.59	65.99	65.79
SEm±	***0.12***	***0.15***	***0.10***	***0.016***	***0.009***	***0.009***	***0.020***	***0.017***	***0.013***	***0.011***	***0.014***	***0.009***	***0.19***	***0.10***	***0.11***
CD(P=0.05)	***0.46***	***0.61***	***0.32***	***0.063***	***0.035***	***0.030***	***0.079***	***0.068***	***0.043***	***0.042***	***0.054***	***0.029***	***0.73***	***0.39***	***0.34***
B_0	98.41	100.03	99.22	5.64	5.66	5.65	27.02	26.97	27.00	4.17	4.12	4.14	43.69	42.85	43.27
B_1	104.78	105.32	105.05	6.12	6.12	6.12	27.98	28.08	28.03	4.62	4.57	4.60	50.58	50.23	50.40
B_2	112.04	112.32	112.18	6.60	6.58	6.59	28.95	28.99	28.97	5.06	5.06	5.06	58.63	58.25	58.44
SEm±	***0.14***	***0.19***	***0.12***	***0.013***	***0.006***	***0.007***	***0.027***	***0.017***	***0.016***	***0.011***	***0.020***	***0.011***	***0.13***	***0.09***	***0.08***
CD(P=0.05)	***0.44***	***0.59***	***0.35***	***0.040***	***0.018***	***0.021***	***0.084***	***0.051***	***0.046***	***0.033***	***0.063***	***0.033***	***0.41***	***0.28***	***0.23***
P_0	103.70	104.13	103.91	5.98	5.99	5.98	27.65	27.72	27.69	4.50	4.45	4.48	49.65	49.49	49.57
P_1	106.46	107.65	107.05	6.26	6.26	6.26	28.32	28.30	28.31	4.73	4.72	4.72	52.28	51.39	51.83
SEm±	***0.14***	***0.24***	***0.14***	***0.011***	***0.007***	***0.006***	***0.026***	***0.016***	***0.015***	***0.009***	***0.009***	***0.006***	***0.14***	***0.09***	***0.08***
CD(P=0.05)	***0.43***	***0.70***	***0.40***	***0.033***	***0.019***	***0.019***	***0.078***	***0.047***	***0.044***	***0.026***	***0.026***	***0.018***	***0.42***	***0.25***	***0.23***

K, S and B uptake by seeds. However, S_2 was found to be significant over treatment S_1 and S_0.

The present finding is in congruence with the observation of Najar *et al.* (2011) and Sharma *et al.* (2014) who reported that sulphur application significantly increases the N, P, K and S uptake by seeds in soybean. The increased in N uptake might be due to the role of sulphur in the enzyme activity responsible for the reduction of nitrate in plants (Sharma *et al*., 2014). Singh *et al*., (2001) observed that application of S stimulates the uptake of P and K in crops. The increased nutrient N, P, K, S and B uptake was also observed by Longkumer *et al.* (2017) with sulphur application. The improved soil nutrient availability and increased root activity resulted in higher nutrient uptake by the crops through combined applicationt of N and S (Wani *et al*., 2000).

4.4.4.2. Effect of boron on N, P, K, S and B uptake by seeds

The results on the effects of sulphur on N, P, K, S and B uptake by seeds has been presented on Table 4.4.4 (a). It has been found that application of boron up to 2 kg ha^{-1} had a significant influence on nutrient uptake by seeds. As evident from the results, the maximum N, P, K, S and B uptake by seeds was observed with application of B_2 which recorded 112.04 kg ha^{-1} and 112.32 kg ha^{-1}, 6.60 kg ha^{-1} and 6.58 kg ha^{-1}, 28.95 kg ha^{-1} and 28.99 kg ha^{-1}, 5.06 kg ha^{-1} and 5.06 kg ha^{-1}, and 58.63 g ha^{-1} and 58.25 g ha^{-1} during 2016 and 2017, respectively, while in the pooled data it was 112.18 kg ha^{-1}, 6.59 kg ha^{-1}, 28.97 kg ha^{-1}, 5.06 kg ha^{-1} and 58.44 g ha^{-1}, respectively. The lowest uptake of N, P, K, S and B by seeds has been observed with B_0 which recorded 98.41 kg ha^{-1} and 100.03 kg ha^{-1}, 5.64 kg ha^{-1} and 5.66 kg ha^{-1}, 27.02 kg ha^{-1} and 26.97 kg ha^{-1}, 4.17 kg ha^{-1} and 4.12 kg ha^{-1}, and 43.69 g ha^{-1} and 42.85 g ha^{-1} during 2016 and 2017, respectively while in the pooled data it was 99.22 kg ha^{-1}, 5.65 kg ha^{-1}, 27.00 kg ha^{-1}, 4.14 kg ha^{-1} and 43.27 g ha^{-1} respectively. Among the different levels of boron, B_2 was found to be significantly higher than B_1 and B_0.

Chaithra and Hebsur (2018) revealed that the uptake of nutrients, N, P, K and B by soybean were significantly influenced by boron application. Similar results on B uptake by grain were reported by Rathod *et al.* (2016) with soil and foliar application of boron through borax. Patel and Zinzala (2018) opined that application of boron significantly increased the N, P, K, S and B uptake by pods in summer groundnut. Sarker *et al.* (2002) and Meshram *et al.* (2017) observed increased in S and B uptake by seeds with application of boron. Improved vegetative growth and dry matter production, seed and stover yield might have been responsible for the higher uptake of nutrients.

4.4.4.3. Effect of phosphorus solubilizing biofertilizer on N, P, K, S and B uptake by seeds

Table 4.4.4 (a) presented the results on the effects of phosphorus solubilizing biofertilizer on N, P, K, S and B uptake by seeds. It has been observed that application of phosphorus solubilizing biofertilizer had a significant effect on the uptake of N, P, K, S and B by seeds. The maximum uptake of P, K, S and B by seeds was observed with P_1 which recorded 106.46 kg ha^{-1} and 107.65 kg ha^{-1}, 6.26 kg ha^{-1} and 6.26 kg ha^{-1}, 28.32 kg ha^{-1} and 28.30 kg ha^{-1}, 4.73 kg ha^{-1} and 4.72 kg ha^{-1}, and 52.28 g ha^{-1} and 51.39 g ha^{-1}, respectively, while in the pooled it recorded 107.05 kg ha^{-1}, 6.26 kg ha^{-1}, 28.31 kg ha^{-1}, 4.72 kg ha^{-1} and 51.83 g ha^{-1}, respectively. The lowest uptake of P, K, S and B by seeds was observed with P_0 which recorded 103.70 kg ha^{-1} and 104.13 kg ha^{-1}, 5.98 kg ha^{-1} and 5.99 kg ha^{-1}, 27.65 kg ha^{-1} and 27.72 kg ha^{-1}, 4.50 kg ha^{-1} and 4.45 kg ha^{-1}, and 49.65 g ha^{-1} and 49.49 g ha^{-1}, respectively, while in the pooled it recorded 103.91 kg ha^{-1}, 5.98 kg ha^{-1}, 27.69 kg ha^{-1}, 4.48 kg ha^{-1} and 49.57 g ha^{-1}, respectively. Treatment P_1 was found to be significant over P_0.

Dhage *et al.* (2008) revealed that dual inoculation of *rhizobium* + PSB resulted in higher uptake of N, P and K by soybean. Devi *et al.* (2012) observed higher uptake of P by seeds with application of SSP + PSB. The application of phosphorus solubilizing biofertilizer might have resulted in higher solubilization of the fixed phosphate in soil and increased its availability which is essential for proper root development and nodulations. The increased nutrient uptake might be due to well developed root system which facilitates higher water and nutrients absorption from the soil. Son *et al.* (2006) also opined that application of phosphate solubilizing bacteria enhanced higher nutrient uptake by soybean.

4.4.4.4. Effect of sulphur and boron interaction on N, P, K, S and B uptake by seeds

The interaction effect between sulphur and boron on N, P, K, S and B uptake by seeds has been presented in Table 4.4.4 (b). It was observed that increasing the level of boron up to 2 kg B ha^{-1} at all levels of sulphur application significantly increased the N, P, K, S and B uptake by seeds. The highest N, P, K, S and B uptake by seeds was observed with S_2B_2 which recorded 135.08 kg ha^{-1} and 134.73 kg ha^{-1}, 8.17 kg ha^{-1} and 8.19 kg ha^{-1}, 32.17 kg ha^{-1} and 32.00 kg ha^{-1}, 6.27 kg ha^{-1} and 6.27 kg ha^{-1}, and 70.35 g ha^{-1} and 71.37 g ha^{-1} during 2016 and 2017, respectively, while in the pooled it was 134.90 kg ha^{-1}, 8.18 kg ha^{-1}, 32.08 kg ha^{-1}, 6.27 kg ha^{-1} and 70.86 g ha^{-1}. The lowest N, P, K, S and B uptake by seeds was observed with S_0B_0 which recorded 85.17 kg ha^{-1} and 84.60 kg ha^{-1}, 4.18 kg ha^{-1} and 4.18 kg ha^{-1}, 24.60 kg ha^{-1} and 24.34 kg ha^{-1}, 2.50 kg ha^{-1} and 2.39 kg ha^{-1}, and 22.29 g ha^{-1} and 22.82 g ha^{-1} during 2016 and 2017, respectively, while in the pooled it was 84.89 kg ha^{-1}, 4.18 kg ha^{-1}, 24.47 kg ha^{-1}, 2.44 kg ha^{-1} and 22.56

Table 4.4.4 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on N, P, K, S and B uptake by seeds

Treatments	**N uptake (kg ha^{-1})**			**P uptake (kg ha^{-1})**			**K uptake (kg ha^{-1})**			**S uptake (kg ha^{-1})**			**B uptake (g ha^{-1})**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0B_0	85.17	84.60	84.89	4.18	4.18	4.18	24.60	24.34	24.47	2.50	2.39	2.44	22.29	22.82	22.56
S_0B_1	90.70	90.05	90.38	4.55	4.64	4.60	25.75	25.78	25.77	3.13	3.05	3.09	32.78	32.48	32.63
S_0B_2	93.21	93.42	93.31	5.10	5.08	5.09	26.07	26.16	26.11	3.65	3.64	3.64	44.44	43.75	44.10
S_1B_0	95.42	97.51	96.47	5.56	5.65	5.60	27.04	27.16	27.10	4.32	4.31	4.32	47.72	45.70	46.71
S_1B_1	100.05	101.75	100.90	6.10	6.07	6.09	27.83	28.05	27.94	4.83	4.77	4.80	53.58	51.60	52.59
S_1B_2	107.85	108.82	108.33	6.53	6.49	6.51	28.62	28.81	28.72	5.26	5.28	5.27	61.11	59.63	60.37
S_2B_0	114.64	117.98	116.31	7.17	7.16	7.17	29.43	29.42	29.43	5.68	5.67	5.67	61.04	60.02	60.53
S_2B_1	123.58	124.16	123.87	7.70	7.66	7.68	30.36	30.40	30.38	5.89	5.90	5.90	65.38	66.60	65.99
S_2B_2	135.08	134.73	134.90	8.17	8.19	8.18	32.17	32.00	32.08	6.27	6.27	6.27	70.35	71.37	70.86
SEm±	***0.25***	***0.33***	***0.21***	***0.023***	***0.010***	***0.012***	***0.047***	***0.029***	***0.028***	***0.019***	***0.035***	***0.020***	***0.23***	***0.16***	***0.14***
CD(P=0.05)	***0.76***	***1.03***	***0.61***	***0.070***	***0.032***	***0.036***	***0.14***	***0.088***	***0.080***	***0.057***	***0.108***	***0.058***	***0.70***	***0.49***	***0.41***
S_0P_0	89.11	88.60	88.85	4.51	4.54	4.53	25.18	25.07	25.13	2.98	2.85	2.91	31.02	31.54	31.28
S_0P_1	90.28	90.11	90.19	4.71	4.73	4.72	25.76	25.78	25.77	3.20	3.20	3.20	35.32	34.50	34.91
S_1P_0	99.73	100.90	100.32	5.90	5.91	5.91	27.61	27.79	27.70	4.69	4.67	4.68	53.30	51.41	52.35
S_1P_1	102.48	104.49	103.49	6.23	6.22	6.23	28.05	28.22	28.13	4.92	4.90	4.91	54.98	53.21	54.10
S_2P_0	122.25	122.89	122.57	7.53	7.51	7.52	30.16	30.30	30.23	5.84	5.85	5.84	64.65	65.53	65.09
S_2P_1	126.61	128.35	127.48	7.84	7.83	7.83	31.15	30.91	31.03	6.06	6.04	6.05	66.54	66.45	66.49
SEm±	***0.25***	***0.41***	***0.24***	***0.019***	***0.011***	***0.011***	***0.046***	***0.027***	***0.027***	***0.015***	***0.015***	***0.011***	***0.24***	***0.15***	***0.14***
CD(P=0.05)	***0.74***	***1.22***	***0.69***	***0.057***	***0.034***	***0.032***	***0.14***	***0.081***	***0.076***	***0.045***	***0.045***	***0.031***	***0.72***	***0.44***	***0.41***
B_0P_0	97.31	98.79	98.05	5.52	5.52	5.52	26.74	26.69	26.72	4.09	4.03	4.06	42.93	42.20	42.57
B_0P_1	99.51	101.26	100.39	5.76	5.81	5.78	27.30	27.26	27.28	4.24	4.21	4.23	44.44	43.49	43.96
B_1P_0	103.78	103.90	103.84	6.00	6.01	6.00	27.68	27.74	27.71	4.52	4.44	4.48	49.06	49.24	49.15
B_1P_1	105.78	106.75	106.26	6.24	6.24	6.24	28.28	28.42	28.35	4.72	4.70	4.71	52.10	51.21	51.65
B_2P_0	110.00	109.70	109.85	6.42	6.44	6.43	28.53	28.74	28.63	4.90	4.89	4.89	56.97	57.04	57.00
B_2P_1	114.09	114.94	114.51	6.78	6.73	6.76	29.37	29.24	29.31	5.22	5.23	5.23	60.30	59.46	59.88
SEm±	***0.25***	***0.41***	***0.24***	***0.019***	***0.011***	***0.011***	***0.046***	***0.027***	***0.027***	***0.015***	***0.015***	***0.011***	***0.24***	***0.15***	***0.14***
CD(P=0.05)	***0.74***	***1.22***	***0.69***	***0.057***	***0.034***	***0.032***	***0.14***	***0.081***	***0.076***	***0.045***	***0.045***	***0.031***	***0.72***	***0.44***	***0.41***

kg ha^{-1}, respectively. Treatment S_2B_2 was found to be significant over all other treatment combinations.

Ismail *et al.* (2013), Longkumer *et al.* (2017) and Ravi *et al.* (2017) also reported that combined application of sulphur and boron significantly increases the uptake of N, P, K, S and B by soybean. Increased uptake of S and B with application of sulphur and boron has been reported by Sarker *et al*. (2002) and Devi *et al.* (2012). The mobilization of P into available form by S could be responsible for the improved uptake of P by plants (Sharma *et al*., 2014). The application of S was found to stimulates the uptake of P and K in crops (Singh *et al*., 2001). Increased nutrient uptake might be due to improved nutrient availability with sulphur and boron fertilization resulting in better growth, higher seed and stover yield which actuate more nutrients absorption from the soil.

4.4.4.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B uptake by seeds

Table 4.4.4 (b) showed the results on the effect of sulphur and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B uptake by seeds. The maximum N, P, K, S and B uptake by seeds has been observed with S_2P_1 with corresponding values of 126.61 kg ha^{-1} and 128.35 kg ha^{-1}, 7.84 kg ha^{-1} and 7.83 kg ha^{-1}, 31.15 kg ha^{-1} and 30.91 kg ha^{-1}, 6.06 kg ha^{-1} and 6.04 kg ha^{-1}, and 66.54 g ha^{-1} and 66.45 g ha^{-1} during 2016 and 2017, respectively and in the pooled it was 127.48 kg ha^{-1}, 7.83 kg ha^{-1}, 31.03 kg ha^{-1}, 6.05 kg ha^{-1} and 66.49 g ha^{-1}. The lowest N, P, K, S and B uptake by seeds was observed with 89.11 kg ha^{-1} and 88.60 kg ha^{-1}, 4.51 kg ha^{-1} and 4.54 kg ha^{-1}, 25.18 kg ha^{-1} and 25.07 kg ha^{-1}, 2.98 kg ha^{-1} and 2.85 kg ha^{-1}, and 31.02 g ha^{-1} and 31.54 g ha^{-1} during 2016 and 2017, respectively, while in the pooled data it was 88.85 kg ha^{-1}, 4.53 kg ha^{-1}, 25.13 kg ha^{-1}, 2.91 kg ha^{-1} and 31.28 g ha^{-1}, respectively. It has been revealed that application of phosphorus solubilizing biofertilizer at all levels of sulphur application increase the nutrient uptake by seeds. As apparent from the results, treatment S_2P_1 was observed to be significant over other treatment combinations.

The increased nutrient N, P, K, S and B uptake was also observed by Longkumer *et al.* (2017) with sulphur application. Dhage *et al.* (2008) revealed that dual inoculation of *rhizobium* + PSB resulted in higher uptake of N, P and K by soybean even in the absence of chemical fertilizers. The increased uptake of N by seeds might be due to improved root nodulations and nitrogen fixation. The mobilization of P into available form by S could be responsible for the improved uptake of P by plants (Sharma *et al*., 2014). Singh *et al*. (2001) observed that application of S stimulates the uptake of P and K in crops. Well developed root system, higher dry matter production, seed and stover yield as a result of improved nutrient availability might be responsible for higher nutrient uptake by seeds.

4.4.4.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B uptake by seeds

The interaction effect of boron and phosphorus solubilizing biofertilizer on N, P, K, S and B uptake by seeds has been presented in Table 4.4.4 (b). The results indicated that application of 2 kg B ha^{-1} (B_2) along with phosphorus solubilizing biofertilizer (P_1) *i.e.*, B_2P_1 recorded the maximum uptake of N, P, K, S and B by seeds with corresponding values of 114.09 kg ha^{-1} and 114.94 kg ha^{-1}, 6.78 kg ha^{-1} and 6.73 kg ha^{-1}, 29.37 kg ha^{-1} and 29.24 kg ha^{-1}, 5.22 kg ha^{-1} and 5.23 kg ha^{-1}, and 60.30 g ha^{-1} and 59.49 g ha^{-1} during 2016 and 2017, respectively. The lowest N, P, K, S and B uptake by seeds has been observed with B_0P_0 which recorded 97.31 kg ha^{-1} and 98.79 kg ha^{-1}, 5.52 kg ha^{-1} and 5.52 kg ha^{-1}, 26.74 kg ha^{-1} and 26.69 kg ha^{-1}, 4.09 kg ha^{-1} and 4.03 kg ha^{-1}, and 42.93 g ha^{-1} and 42.20 g ha^{-1} during 2016 and

2017, respectively. In the pooled data, uptake of N, P, K, S and B by seeds with treatment B_2P_1 recorded an average mean of 114.51 kg ha^{-1}, 6.76 kg ha^{-1}, 29.31 kg ha^{-1}, 5.23 kg ha^{-1} and 59.88 g ha^{-1} while B_0P_0 recorded average mean uptake of 98.05 kg ha^{-1}, 5.52 kg ha^{-1}, 26.72 kg ha^{-1}, 4.06 kg ha^{-1} and 42.57 g ha^{-1}, respectively. It has been observed that the interaction effect of treatment B_2P_1 was found to be significantly higher as compared to other treatment combinations including control treatment.

Phosphorus and boron play a vital in root development and nodulations in soybean. Both phosphorus and boron are deficient in the experimental plot and its increased availability through boron fertilization along with phosphorus solubilizing biofertilizer inoculation might have helped in better root development and nodulations which exploit the soil nutrient reserved resulting in higher nutrient uptake. Sentimenla *et al.* (2012) revealed that N, P, K and B uptake by soybean was significantly increased with different levels of phosphorus and boron fertilization either alone or in combination. Longkumer *et al.* (2017) and Chaithra and Hebsur (2018) revealed that application of boron increases the uptake of N, P, K, S and B by soybean. Sandeep *et al.* (2008) unveiled that inoculation with PSM significantly increased the uptake of N and P by stover. Son *et al.* (2006) also opined that application of phosphate solubilizing bacteria enhanced higher nutrient uptake by soybean.

4.4.4.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B uptake by seeds

Table 4.4.4 (c) presented the results on the effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on N, P, K, S and B uptake by seeds. The results had revealed that application of increased levels of sulphur and boron along with phosphorus solubilizing biofertilizer significantly influenced the

Table 4.4.4 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on N, P, K, S and B uptake by seeds

Treatments	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})			S uptake (kg ha^{-1})			B uptake (g ha^{-1})		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
$S_0B_0P_0$	84.58	83.93	84.26	4.14	4.12	4.13	24.35	23.87	24.11	2.44	2.28	2.36	20.94	21.70	21.32
$S_0B_0P_1$	85.76	85.27	85.51	4.23	4.25	4.24	24.84	24.80	24.82	2.55	2.50	2.53	23.65	23.94	23.79
$S_0B_1P_0$	90.24	88.84	89.54	4.42	4.52	4.47	25.52	25.56	25.54	3.02	2.86	2.94	30.89	31.08	30.99
$S_0B_1P_1$	91.17	91.26	91.21	4.68	4.76	4.72	25.98	26.01	26.00	3.24	3.24	3.24	34.67	33.88	34.27
$S_0B_2P_0$	92.49	93.04	92.77	4.98	4.97	4.98	25.68	25.78	25.73	3.48	3.41	3.45	41.24	41.83	41.53
$S_0B_2P_1$	93.92	93.79	93.86	5.22	5.18	5.20	26.45	26.53	26.49	3.81	3.86	3.84	47.64	45.68	46.66
$S_1B_0P_0$	94.36	96.39	95.37	5.40	5.42	5.41	26.76	26.98	26.87	4.22	4.22	4.22	47.26	45.35	46.30
$S_1B_0P_1$	96.49	98.63	97.56	5.71	5.87	5.79	27.32	27.34	27.33	4.42	4.40	4.41	48.19	46.05	47.12
$S_1B_1P_0$	98.89	100.74	99.82	6.00	5.97	5.99	27.65	27.74	27.69	4.68	4.62	4.65	52.23	50.28	51.26
$S_1B_1P_1$	101.21	102.76	101.99	6.21	6.16	6.19	28.01	28.36	28.18	4.98	4.92	4.95	54.92	52.92	53.92
$S_1B_2P_0$	105.95	105.56	105.76	6.30	6.33	6.32	28.42	28.67	28.54	5.16	5.17	5.16	60.40	58.60	59.50
$S_1B_2P_1$	109.74	112.08	110.91	6.76	6.64	6.70	28.82	28.96	28.89	5.37	5.38	5.38	61.82	60.66	61.24
$S_2B_0P_0$	112.99	116.07	114.53	7.01	7.02	7.02	29.11	29.21	29.16	5.60	5.60	5.60	60.61	59.55	60.08
$S_2B_0P_1$	116.29	119.88	118.09	7.34	7.31	7.32	29.75	29.63	29.69	5.76	5.73	5.74	61.48	60.49	60.98
$S_2B_1P_0$	122.21	122.11	122.16	7.58	7.52	7.55	29.87	29.92	29.90	5.85	5.85	5.85	64.06	66.37	65.21
$S_2B_1P_1$	124.95	126.22	125.59	7.82	7.80	7.81	30.85	30.88	30.87	5.93	5.95	5.94	66.70	66.82	66.76
$S_2B_2P_0$	131.56	130.50	131.03	7.99	8.00	8.00	31.48	31.77	31.63	6.06	6.08	6.07	69.27	70.68	69.98
$S_2B_2P_1$	138.59	138.95	138.77	8.35	8.38	8.36	32.86	32.22	32.54	6.49	6.45	6.47	71.43	72.05	71.74
SEm±	***0.43***	***0.71***	***0.41***	***0.033***	***0.020***	***0.019***	***0.079***	***0.047***	***0.046***	***0.027***	***0.027***	***0.019***	***0.42***	***0.26***	***0.25***
CD(P=0.05)	***1.28***	***2.11***	***1.19***	***0.10***	***0.06***	***0.06***	***0.23***	***0.14***	***0.13***	***0.08***	***0.08***	***0.054***	***1.25***	***0.76***	***0.70***

nutrient uptake by seeds. The maximum N, P, K, S and B uptake by seeds was observed with treatment $S_2B_2P_1$ which recorded 138.59 kg ha^{-1} and 138.95 kg ha^{-1}, 8.35 kg ha^{-1} and 8.38 kg ha^{-1}, 32.86 kg ha^{-1} and 32.22 kg ha^{-1}, 6.49 kg ha^{-1} and 6.45 kg ha^{-1}, and 71.43 g ha^{-1} and 72.05 g ha^{-1} during 2016 and 2017, respectively whereas, the lowest uptake was observed with $S_0B_0P_0$ (control) which recorded 84.58 kg ha^{-1} and 83.93 kg ha^{-1}, 4.14 kg ha^{-1} and 4.12 kg ha^{-1}, 24.35 kg ha^{-1} and 23.87 kg ha^{-1}, 2.44 kg ha^{-1} and 2.28 kg ha^{-1}, and 20.94 g ha^{-1} and 21.70 g ha^{-1} during 2016 and 2017, respectively. From the pooled data, it has been revealed that $S_2B_2P_1$ which recorded an average mean uptake of 138.77 kg ha^{-1}, 8.36 kg ha^{-1}, 32.54 kg ha^{-1}, 6.47 kg ha^{-1} and 71.74 g ha^{-1} whereas, $S_0B_0P_0$ (control) recorded an average mean uptake of 84.26 kg ha^{-1}, 4.13 kg ha^{-1}, 24.11 kg ha^{-1}, 2.36 kg ha^{-1} and 21.32 g ha^{-1}, respectively. A gradual increase in the uptake of N, P, K, S and B by seeds has been observed with increasing levels of sulphur and boron application along with phosphorus solubilizing biofertilizer as seed treatment. However, treatment $S_2B_2P_1$ was found to be significant over other treatment combinations.

The improved nutrient availability through sulphur and boron fertilization along with solubilizing biofertilizer inoculation might be responsible for the higher nutrient uptake by the plants. Ismail *et al.* (2013), Longkumer *et al.* (2017) and Ravi *et al.* (2017) also reported that combined application of sulphur and boron significantly increases the uptake of N, P, K, S and B by soybean. Son *et al.* (2006), Argaw (2012) and Devi *et al.* (2012) also reported that inoculation with PSB resulted in higher uptake of nutrients by soybean.

4.4.5 Effect on total uptake of N, P, K, S and B by plants

4.4.5.1. Effect of sulphur on total uptake of N, P, K, S and B by plants

Table 4.4.5 (a) and Fig. 8 showed the result on the effect of sulphur on total uptake N, P, K, S and B by plants. The highest total uptake of N, P, K, S and B by plants was observed with S_2 which recorded 188.82 kg ha^{-1} and 191.25 kg ha^{-1}, 17.04 kg ha^{-1} and 16.92 kg ha^{-1}, 96.46 kg ha^{-1} and 96.59 kg ha^{-1}, 15.48 kg ha^{-1} and 15.51 kg ha^{-1}, and 126.61 g ha^{-1} and 127.74 kg ha^{-1} during 2016 and 2017, respectively while in the it recorded 190.04 kg ha^{-1}, 16.98 kg ha^{-1}, 96.53 kg ha^{-1}, 15.49 kg ha^{-1} and 127.17 g ha^{-1}, respectively. The lowest total uptake of N, P, K, S and B by plants was observed with S_0 which recorded 137.12 kg ha^{-1} and 137.72 kg ha^{-1}, 10.76 kg ha^{-1} and 10.81 kg ha^{-1}, 75.64 kg ha^{-1} and 75.94 kg ha^{-1}, 10.33 kg ha^{-1} and 10.11 kg ha^{-1}, and 63.43 g ha^{-1} and 63.14 g ha^{-1} during 2016 and 2017, respectively while in the pooled it had 137.42 kg ha^{-1}, 10.78 kg ha^{-1}, 75.79 kg ha^{-1}, 10.22 kg ha^{-1} and 63.28 g ha^{-1}, respectively. It has been observed that increasing the levels of sulphur up to 40 kg S ha^{-1} significantly increases the total uptake of N, P, K, S and B by soybean. As evident from the results, S_2 level of sulphur application was found to be significant over S_1 and S_0.

The results are in accordance with the findings of Ismail *et al.* (2013) and Longkumer *et al.* (2017) who also observed that the total nutrients uptake of N, P, K, S and B by soybean were significantly increase with sulphur application. The essential role of sulphur in the enzyme activity associated with nitrate reduction in plants might be responsible for higher total uptake of N. The mobilization of P into available form by S might have resulted in higher uptake of P by the plants (Sharma *et al.,* 2014). Singh *et al.* (2001) opined that the presence of S induces higher uptake P and K by plants. Ganeshamurthy (1996), Majumdar *et al.* (2001) also observed that sulphur application increases the uptake of S by plants.

Table 4.4.5 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on total uptake of N, P, K, S and B by plants

Treatments	**N uptake (kg ha^{-1})**			**P uptake (kg ha^{-1})**			**K uptake (kg ha^{-1})**			**S uptake (kg ha^{-1})**			**B uptake (g ha^{-1})**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	137.12	137.72	137.42	10.76	10.81	10.78	75.64	75.94	75.79	10.33	10.11	10.22	63.43	63.14	63.28
S_1	152.47	155.81	154.14	13.85	14.13	13.99	86.14	86.35	86.24	13.15	13.29	13.22	102.79	100.49	101.64
S_2	188.82	191.25	190.04	17.04	16.92	16.98	96.46	96.59	96.53	15.48	15.51	15.49	126.61	127.74	127.17
SEm±	***0.23***	***0.31***	***0.19***	***0.06***	***0.03***	***0.04***	***0.21***	***0.12***	***0.12***	***0.011***	***0.011***	***0.008***	***0.17***	***0.15***	***0.11***
CD(P=0.05)	***0.89***	***1.22***	***0.63***	***0.25***	***0.12***	***0.12***	***0.81***	***0.48***	***0.39***	***0.043***	***0.045***	***0.026***	***0.67***	***0.58***	***0.37***
B_0	150.00	152.99	151.50	12.71	12.94	12.82	82.76	82.86	82.81	12.08	12.04	12.06	85.04	83.97	84.50
B_1	158.95	161.02	159.99	14.05	13.99	14.02	86.05	86.28	86.16	13.05	12.98	13.01	97.51	97.32	97.42
B_2	169.45	170.78	170.12	14.90	14.94	14.92	89.44	89.73	89.59	13.83	13.89	13.86	110.28	110.08	110.18
SEm±	***0.18***	***0.25***	***0.15***	***0.07***	***0.03***	***0.04***	***0.12***	***0.07***	***0.07***	***0.015***	***0.017***	***0.011***	***0.13***	***0.14***	***0.10***
CD(P=0.05)	***0.54***	***0.78***	***0.45***	***0.21***	***0.10***	***0.11***	***0.38***	***0.21***	***0.20***	***0.047***	***0.051***	***0.033***	***0.41***	***0.42***	***0.28***
P_0	157.25	158.96	158.11	13.39	13.46	13.43	85.09	85.43	85.26	12.76	12.71	12.73	95.00	94.94	94.97
P_1	161.69	164.23	162.96	14.38	14.44	14.41	87.07	87.15	87.11	13.22	13.23	13.22	100.22	99.30	99.76
SEm±	***0.17***	***0.26***	***0.16***	***0.05***	***0.02***	***0.03***	***0.05***	***0.06***	***0.04***	***0.015***	***0.017***	***0.012***	***0.16***	***0.11***	***0.10***
CD(P=0.05)	***0.51***	***0.78***	***0.45***	***0.15***	***0.06***	***0.08***	***0.16***	***0.16***	***0.11***	***0.046***	***0.052***	***0.033***	***0.48***	***0.33***	***0.28***

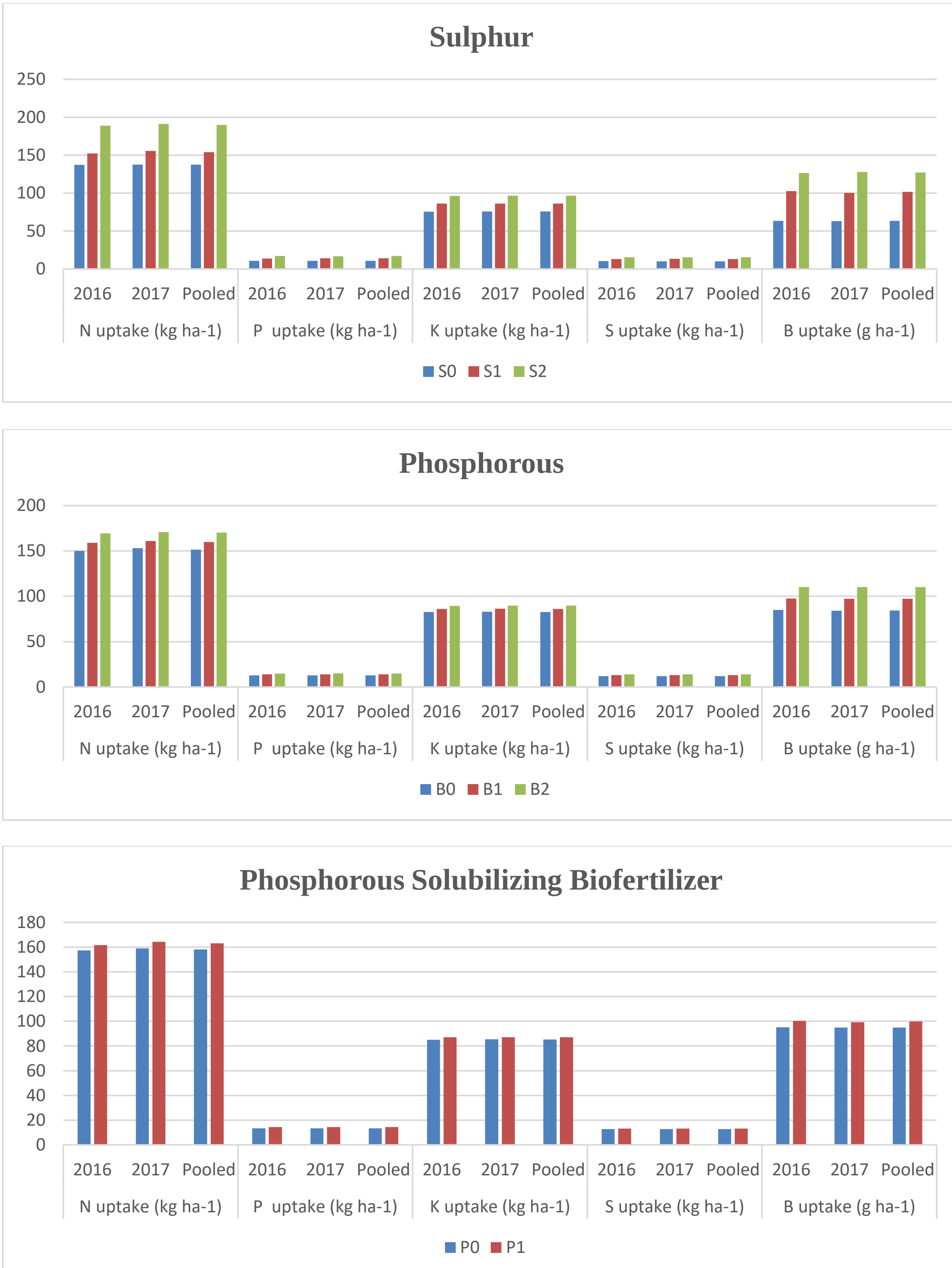


Fig. 8: Effect of sulfur, boron and phosphorus solubilizing biofertilizeron total uptake of N, P, K, S and B by plants

Improved root activity, higher dry matter production, seed and stover yield could have facilitated higher nutrients uptake from the soil.

4.4.5.2. Effect of boron on total uptake of N, P, K, S and B by plants

The result on the effects of boron on total uptake of N, P, K, S and B by plants has been presented on Table 4.4.5 (a) and Fig. 5. The results revealed that application of boron up to 2 kg ha^{-1} significantly increases the total uptake of N, P, K, S and B by plants. Application B_2 was observed to have the maximum total uptake of N, P, K, S and B by plants which recorded 169.45 kg ha^{-1} and 170.78 kg ha^{-1}, 14.90 kg ha^{-1} and 14.94 kg ha^{-1}, 89.44 kg ha^{-1} and 89.73 kg ha^{-1}, 13.83 kg ha^{-1} and 13.89 kg ha^{-1}, and 110.28 g ha^{-1} and 110.08 g ha^{-1} during 2016 and 2017, respectively while in the pooled it was 170.12 kg ha^{-1}, 14.92 kg ha^{-1}, 89.59 kg ha^{-1}, 13.86 kg ha^{-1} and 110.18 g ha^{-1}, respectively. The lowest total uptake of N, P, K, S and B by plants was observed with application of B_0 (0 kg B ha^{-1}) which recorded 150.00 kg ha^{-1} and 152.99 kg ha^{-1}, 12.71 kg ha^{-1} and 12.94 kg ha^{-1}, 82.76 kg ha^{-1} and 82.86 kg ha^{-1}, 12.08 kg ha^{-1} and 12.04 kg ha^{-1}, and 85.04 g ha^{-1} and 83.97 g ha^{-1} during 2016 and 2017, respectively while in pooled data it was 151.50 kg ha^{-1}, 12.82 kg ha^{-1}, 82.81 kg ha^{-1}, 12.06 kg ha^{-1} and 84.50 g ha^{-1}, respectively. Application of B_2 recorded significantly higher total uptake of N, P, K, S and B by plants as compared to B_1 and B_0.

Chaithra and Hebsur (2018) found that the total uptake of N, P, K and S were significantly increased with application of boron. Increased total uptake of N, P, K, S and B by soybean has also been reported by Longkumer *et al.* (2017). Rahman *et al.* (2004) also observed increased uptake of N, P and K with application of 1.5 kg B ha^{-1}. Kundu *et al.* (2016) opined that S and B uptake are significantly influenced by boron application. Increased dry matter production, higher seed and stover yield might be responsible for higher nutrient uptake by soybean (Chaithra and Hebsur, 2018).

4.4.5.3. Effect of phosphorus solubilizing biofertilizer on total uptake of N, P, K, S and B by plants

Table 4.4.5 (a) and Fig. 5 presented the effect of phosphorus solubilizing biofertilizer on total uptake of N, P, K, S and B by plants. It was observed that application of phosphorus solubilizing biofertilizer (P_1) recorded higher total uptake of N, P, K, S and B by plants which recorded 161.69 kg ha^{-1} and 164.23 kg ha^{-1}, 14.38 kg ha^{-1} and 14.44 kg ha^{-1}, 87.07 kg ha^{-1} and 87.15 kg ha^{-1}, 13.22 kg ha^{-1} and 13.23 kg ha^{-1}, and 100.22 g ha^{-1} and 99.30 g ha^{-1} as compared to P_0 which recorded 157.25 kg ha^{-1} and 158.11 kg ha^{-1}, 13.39 kg ha^{-1} and 13.46 kg ha^{-1}, 85.09 kg ha^{-1} and 85.43 kg ha^{-1}, 12.76 kg ha^{-1} and 12.71kg ha^{-1}, and 95.00 g ha^{-1} and 94.94 g ha^{-1} during 2016 and 2017, respectively. In the pooled data, P_1 recorded an average mean total uptake of N, P, K, S and B by plants of 162.96 kg ha^{-1}, 14.41 kg ha^{-1}, 87.11 kg ha^{-1}, 13.22 kg ha^{-1} and 99.76 g ha^{-1} whereas, P_0 recorded 158.11 kg ha^{-1}, 13.43 kg ha^{-1}, 85.26 kg ha^{-1}, 12.73 kg ha^{-1} and 94.97 g ha^{-1}, respectively. Treatment P_1 was found to be significant over P_0.

Soil acidity induced P deficiency were observed in the experimental plot and its increased mineralization through phosphorus solubilizing biofertilizer (P_1) application must have resulted in better root development prompting the active roots to absorbed more nutrients from the soil. Dhage *et al.* (2008) revealed that even in the absence of chemical fertilizers, dual inoculation with (*Rhizobium* + PSB) resulted in higher N, P and K uptake by soybean. Son *et al.* (2006) and Sandeep *et al.* (2008) revealed that application of phosphate solubilizing bacteria increases the nutrient uptake by soybean.

4.4.5.4. Effect of sulphur and boron interaction on total uptake of N, P, K, S and B by plants

The interaction effect of sulphur and boron on total uptake of N, P, K, S and B by plants has been presented in Table 4.4.5 (b). It was evident from the results that increasing the levels of boron at all levels of sulphur application significantly increases the total uptake of N, P, K, S and B by plants. The maximum total uptake of N, P, K, S and B by plants was observed with treatment S_2B_2 which recorded 2014.87 kg ha^{-1} and 204.95 kg ha^{-1}, 17.86 kg ha^{-1} and 17.96 kg ha^{-1}, 100.48 kg ha^{-1} and 100.64 kg ha^{-1}, 16.15 kg ha^{-1} and 16.17 kg ha^{-1}, 135.01 g ha^{-1} and 136.72 g ha^{-1} during 2016 and 2017, respectively, while the pooled data had 204.91 kg ha^{-1}, 17.91 kg ha^{-1}, 100.56 kg ha^{-1}, 16.16 kg ha^{-1} and 135.86 g ha^{-1}, respectively. The lowest total N, P, K, S and B uptake by plants was observed with treatment S_0B_0 which recorded 131.53 kg ha^{-1} and 131.95 kg ha^{-1}, 9.59 kg ha^{-1} and 9.73 kg ha^{-1}, 73.21 kg ha^{-1} and 73.21 kg ha^{-1}, 8.92 kg ha^{-1} and 8.74 kg ha^{-1}, 45.18 g ha^{-1} and 45.56 g ha^{-1} during 2016 and 2017, respectively, while the pooled data had 131.74 kg ha^{-1}, 9.66 kg ha^{-1}, 73.21 kg ha^{-1}, 8.83 kg ha^{-1} and 45.37 g ha^{-1}, respectively. There was significant difference among the different treatments on the total uptake of N, P, K, S and B uptake by plants. However, treatment S_2B_2 was found to have significantly higher total uptake of N, P, K, S and B uptake by plants compared to other treatments.

Longkumer *et al.* (2017) and Ravi *et al.* (2017) observed significant increase in N, P, K, S and B uptake by soybean with sulphur and boron application. Patel and Zinzala (2018) revealed that the interaction between sulphur and boron had significant influence on total S and B uptake by groundnut. The increased N uptake might be due to favourable effect of sulphur and boron on root nodulation and higher nitrogen fixation. The mobilization of P into available form

Table 4.4.5 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on total uptake of N, P, K, S and B by plants

Treatments	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})			S uptake (kg ha^{-1})			B uptake (g ha^{-1})		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0B_0	131.53	131.95	131.74	9.59	9.73	9.66	73.21	73.21	73.21	8.92	8.74	8.83	45.18	45.56	45.37
S_0B_1	138.19	138.04	138.11	10.98	10.74	10.86	75.66	75.96	75.81	10.66	10.20	10.43	63.95	63.47	63.71
S_0B_2	141.64	143.19	142.41	11.71	11.95	11.83	78.07	78.65	78.36	11.40	11.39	11.40	81.17	80.38	80.78
S_1B_0	144.72	148.71	146.71	12.53	13.23	12.88	82.23	82.36	82.30	12.45	12.53	12.49	91.24	87.98	89.61
S_1B_1	150.83	154.53	152.68	13.89	14.27	14.08	86.41	86.76	86.59	13.09	13.24	13.16	102.48	100.36	101.42
S_1B_2	161.85	164.20	163.02	15.13	14.90	15.02	89.78	89.92	89.85	13.93	14.09	14.01	114.66	113.13	113.90
S_2B_0	173.77	178.31	176.04	16.01	15.85	15.93	92.84	93.01	92.93	14.88	14.86	14.87	118.71	118.37	118.54
S_2B_1	187.84	190.50	189.17	17.27	16.95	17.11	96.07	96.13	96.10	15.41	15.49	15.45	126.10	128.14	127.12
S_2B_2	204.87	204.95	204.91	17.86	17.96	17.91	100.48	100.64	100.56	16.15	16.17	16.16	135.01	136.72	135.86
SEm±	***0.31***	***0.44***	***0.27***	***0.12***	***0.05***	***0.07***	***0.21***	***0.12***	***0.12***	***0.027***	***0.029***	***0.020***	***0.23***	***0.24***	***0.17***
CD(P=0.05)	***0.94***	***1.35***	***0.78***	***0.36***	***0.17***	***0.19***	***0.65***	***0.37***	***0.35***	***0.082***	***0.089***	***0.057***	***0.71***	***0.73***	***0.48***
S_0P_0	136.26	136.61	136.44	10.11	10.31	10.21	74.91	75.22	75.06	10.03	9.73	9.88	59.85	60.59	60.22
S_0P_1	137.98	138.84	138.41	11.41	11.31	11.36	76.37	76.66	76.52	10.62	10.49	10.55	67.02	65.68	66.35
S_1P_0	150.10	152.88	151.49	13.47	13.65	13.56	85.22	85.40	85.31	12.97	13.07	13.02	100.43	98.00	99.21
S_1P_1	154.83	158.74	156.78	14.23	14.62	14.42	87.07	87.29	87.18	13.34	13.50	13.42	105.15	102.98	104.06
S_2P_0	185.38	187.40	186.39	16.59	16.44	16.51	95.15	95.68	95.42	15.27	15.32	15.30	124.73	126.24	125.48
S_2P_1	192.27	195.11	193.69	17.50	17.40	17.45	97.77	97.50	97.64	15.69	15.69	15.69	128.48	129.24	128.86
SEm±	***0.29***	***0.46***	***0.27***	***0.09***	***0.04***	***0.05***	***0.09***	***0.10***	***0.07***	***0.027***	***0.030***	***0.020***	***0.28***	***0.19***	***0.17***
CD(P=0.05)	***0.88***	***1.35***	***0.78***	***0.26***	***0.11***	***0.14***	***0.27***	***0.28***	***0.19***	***0.080***	***0.090***	***0.058***	***0.83***	***0.57***	***0.49***
B_0P_0	148.39	151.01	149.70	12.43	12.51	12.47	81.88	81.87	81.87	11.86	11.82	11.84	82.92	82.09	82.50
B_0P_1	151.61	154.97	153.29	12.99	13.37	13.18	83.64	83.85	83.75	12.31	12.27	12.29	87.16	85.85	86.51
B_1P_0	157.10	158.84	157.97	13.48	13.49	13.49	85.20	85.50	85.35	12.84	12.69	12.77	95.04	94.96	95.00
B_1P_1	160.80	163.20	162.00	14.61	14.48	14.55	86.89	87.06	86.98	13.26	13.26	13.26	99.97	99.68	99.83
B_2P_0	166.24	167.04	166.64	14.26	14.39	14.32	88.21	88.93	88.57	13.57	13.62	13.59	107.05	107.78	107.41
B_2P_1	172.67	174.51	173.59	15.54	15.48	15.51	90.68	90.54	90.61	14.08	14.15	14.12	113.51	112.37	112.94
SEm±	***0.29***	***0.46***	***0.27***	***0.09***	***0.04***	***0.05***	***0.09***	***0.10***	***0.07***	***0.027***	***0.030***	***0.020***	***0.28***	***0.19***	***0.17***
CD(P=0.05)	***0.88***	***1.35***	***0.78***	***0.26***	***0.11***	***0.14***	***0.27***	***0.28***	***0.19***	***0.080***	***0.090***	***0.058***	***0.83***	***0.57***	***0.49***

by S might have resulted in higher uptake of P by the plants (Sharma *et al.,* 2014). Singh *et al.* (2001) opined that the presence of S induce higher uptake of P and K by plants. The increased in total S and B uptake by soybean might be due to its improved availability through sulphur and boron application.

4.4.5.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on total uptake of N, P, K, S and B by plants

The results on the effects of interaction between sulphur and phosphorus solubilizing biofertilizer on total uptake of N, P, K, S and B by plants has been presented in Table 4.4.5 (b). It was observed that application of sulphur along with phosphorus solubilizing biofertilizer significantly increases the total uptake of N, P, K, S and B by plants than application of increased level of sulphur alone. The maximum total uptake of N, P, K, S and B by plants was observed with S_2P_1 which recorded 192.27 kg ha^{-1} and 195.11 kg ha^{-1}, 17.50 kg ha^{-1} and 17.40 kg ha^{-1}, 97.77 kg ha^{-1} and 97.50 kg ha^{-1}, 15.69 kg ha^{-1} and 15.69 kg ha^{-1}, and 128.48 g ha^{-1} and 129.24 g ha^{-1} during 2016 and 2017, respectively, while the pooled data had 193.69 kg ha^{-1}, 17.45 kg ha^{-1}, 97.64 kg ha^{-1}, 15.69 kg ha^{-1} and 128.86 g ha^{-1}, respectively. The lowest total uptake of N, P, K, S and B by plants was observed with S_0P_0 which recorded 136.26 kg ha^{-1} and 136.61 kg ha^{-1}, 10.11 kg ha^{-1} and 10.31 kg ha^{-1}, 74.91 kg ha^{-1} and 75.22 kg ha^{-1}, 10.03 kg ha^{-1} and 9.73 kg ha^{-1}, and 59.85 g ha^{-1} and 60.59 g ha^{-1} during 2016 and 2017, respectively, while the pooled data had 136.44 kg ha^{-1}, 10.21 kg ha^{-1}, 75.06 kg ha^{-1}, 9.88 kg ha^{-1} and 60.22 g ha^{-1}, respectively. The interaction between sulphur and phosphorus solubilizing biofertilizer had significant influence on the total uptake of N, P, K, S and B by plants. However, S_2P_1 was found to have significantly higher total uptake of N, P, K, S and B by plants.

The increased nutrient N, P, K, S and B uptake was also observed by Longkumer *et al.* (2017) with sulphur application. Dhage *et al.* (2008) revealed that dual inoculation of *rhizobium* + PSB resulted in higher uptake of N, P and K by soybean even in the absence of chemical fertilizers. The increased uptake of N by seeds might be due to improved root nodulations and nitrogen fixation. The mobilization of P into available form by S could be responsible for the improved uptake of P by plants (Sharma *et al*., 2014). Singh *et al*. (2001) observed that application of S stimulates the uptake of P and K in crops. Well developed root system, higher matter production, seed and stover yield as a result of improved nutrient availability might be responsible for higher nutrient uptake by seeds.

4.4.5.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on total uptake of N, P, K, S and B by plants

Table 4.4.5 (b) showed the interaction effect between boron and phosphorus solubilizing biofertilizer on total uptake of N, P, K, S and B by plants. The results revealed that application of boron up to 2 kg B ha^{-1} along with phosphorus solubilizing biofertilizer significantly influence the total uptake of N, P, K, S and B by plants. The maximum total N, P, K, S and B uptake by plants was observed with treatment B_2P_1 which recorded 172.67 kg ha^{-1} and 174.51 kg ha^{-1}, 15.54 kg ha^{-1} and 15.48 kg ha^{-1}, 90.68 kg ha^{-1} and 90.54 kg ha^{-1}, 14.08 kg ha^{-1} and 14.15 kg ha^{-1}, and 113.51 g ha^{-1} and 112.37 g ha^{-1} during 2016 and 2017, respectively, while the pooled data had 173.59 kg ha^{-1}, 15.51 kg ha^{-1}, 90.61 kg ha^{-1}, 14.12 kg ha^{-1} and 112.94 g ha^{-1}, respectively. The minimum total N, P, K, S and B uptake by plants was observed with treatment B_0P_0 which recorded 148.39 kg ha^{-1} and 151.01 kg ha^{-1}, 12.43 kg ha^{-1} and 12.51 kg ha^{-1}, 81.88 kg ha^{-1} and 81.87 kg ha^{-1}, 11.86 kg ha^{-1} and 11.82 kg ha^{-1}, and 82.92 g ha^{-1} and 82.09 g ha^{-1} during 2016 and 2017, respectively, while the pooled data had 149.70 kg ha^{-1}, 12.47 kg ha^{-1}, 81.87 kg ha^{-1}, 11.84 kg ha^{-1} and 82.50 g ha^{-1}, respectively. Among the different treatment, the interaction effect of B_2P_1 on total N, P, K, S and B uptake by plants was found to be significantly higher.

Phosphorus and boron play a vital in root development in plants. Both phosphorus and boron are deficient in the experimental plot and its increased availability through boron fertilization along with phosphorus solubilizing biofertilizer inoculation might have helped in better root development and nodulations which exploit the soil nutrient reserved resulting in higher nutrient uptake. Sentimenla *et al.* (2012) revealed that N, P, K and B uptake by soybean was significantly increased with different levels of phosphorus and boron fertilization either alone or in combination. Longkumer *et al.* (2017) and Chaithra and Hebsur (2018) revealed that application of boron increases the uptake of N, P, K, S and B by soybean. Sandeep *et al.* (2008) unveiled that inoculation with PSM significantly increased the uptake of N and P.

4.4.5.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on total uptake of N, P, K, S and B by plants

The results on the effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on total uptake of N, P, K, S and B by plants has been presented in Table 4.4.5 (c). As evident from the results obtained, increasing the levels of sulphur and boron application along with phosphorus solubilizing biofertilizer significantly enhanced the total N, P, K, S and B uptake by plants. Treatment $S_2B_2P_1$ was observed to have the maximum total N, P, K, S and B uptake by plants with corresponding values of 209.68 kg ha^{-1} and 209.86 kg ha^{-1}, 18.60 kg ha^{-1} and 18.56 kg ha^{-1}, 101.98 kg ha^{-1} and 101.60 kg ha^{-1}, 16.47 kg ha^{-1} and 16.45 kg ha^{-1}, and 137.18 g ha^{-1} and 138.22 g ha^{-1} during 2016 and 2017, respectively, while the pooled data had 209.77 kg ha^{-1}, 18.58 kg ha^{-1}, 101.79 kg

Table 4.4.5 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on total uptake of N, P, K, S and B by plants

Treatments	N uptake (kg ha^{-1})			P uptake (kg ha^{-1})			K uptake (kg ha^{-1})			S uptake (kg ha^{-1})			B uptake (g ha^{-1})		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
$S_0B_0P_0$	130.70	130.83	130.77	9.27	9.32	9.30	72.85	72.48	72.67	8.59	8.41	8.50	42.65	43.92	43.29
$S_0B_0P_1$	132.35	133.06	132.71	9.90	10.15	10.02	73.56	73.94	73.75	9.25	9.07	9.16	47.70	47.20	47.45
$S_0B_1P_0$	137.31	136.59	136.95	9.99	10.08	10.04	75.17	75.70	75.44	10.34	9.70	10.02	60.81	60.40	60.61
$S_0B_1P_1$	139.07	139.48	139.28	11.97	11.39	11.68	76.14	76.21	76.18	10.97	10.71	10.84	67.09	66.54	66.82
$S_0B_2P_0$	140.77	142.40	141.59	11.06	11.52	11.29	76.71	77.46	77.09	11.17	11.09	11.13	76.09	77.46	76.77
$S_0B_2P_1$	142.52	143.97	143.24	12.36	12.38	12.37	79.42	79.84	79.63	11.62	11.69	11.66	86.26	83.29	84.78
$S_1B_0P_0$	143.31	147.04	145.17	12.23	12.74	12.49	81.04	80.93	80.99	12.28	12.34	12.31	89.04	85.57	87.31
$S_1B_0P_1$	146.12	150.37	148.25	12.82	13.71	13.27	83.42	83.79	83.61	12.61	12.72	12.67	93.43	90.38	91.91
$S_1B_1P_0$	149.09	152.94	151.01	13.58	13.90	13.74	85.68	85.63	85.65	12.91	13.01	12.96	100.03	97.76	98.90
$S_1B_1P_1$	152.57	156.12	154.34	14.20	14.64	14.42	87.14	87.90	87.52	13.28	13.46	13.37	104.92	102.95	103.94
$S_1B_2P_0$	157.90	158.67	158.29	14.61	14.30	14.46	88.93	89.66	89.29	13.71	13.87	13.79	112.22	110.65	111.44
$S_1B_2P_1$	165.81	169.72	167.76	15.65	15.50	15.58	90.64	90.17	90.41	14.14	14.32	14.23	117.10	115.61	116.35
$S_2B_0P_0$	171.17	175.17	173.17	15.78	15.47	15.62	91.74	92.19	91.96	14.70	14.71	14.71	117.06	116.77	116.92
$S_2B_0P_1$	176.36	181.46	178.91	16.24	16.24	16.24	93.95	93.83	93.89	15.06	15.01	15.04	120.36	119.96	120.16
$S_2B_1P_0$	184.91	186.99	185.95	16.88	16.49	16.69	94.75	95.17	94.96	15.28	15.35	15.32	124.29	126.73	125.51
$S_2B_1P_1$	190.76	194.00	192.38	17.66	17.41	17.53	97.39	97.08	97.23	15.53	15.62	15.57	127.91	129.55	128.73
$S_2B_2P_0$	200.06	200.04	200.05	17.11	17.35	17.23	98.98	99.68	99.33	15.83	15.89	15.86	132.83	135.22	134.03
$S_2B_2P_1$	209.68	209.86	209.77	18.60	18.56	18.58	101.98	101.60	101.79	16.47	16.45	16.46	137.18	138.22	137.70
SEm±	***0.51***	***0.79***	***0.47***	***0.15***	***0.06***	***0.08***	***0.16***	***0.17***	***0.11***	***0.046***	***0.052***	***0.035***	***0.48***	***0.33***	***0.29***
CD(P=0.05)	***1.52***	***2.34***	***1.35***	***0.46***	***0.19***	***0.24***	***0.47***	***0.49***	***0.33***	***0.14***	***0.16***	***0.10***	***1.43***	***0.99***	***0.84***

ha^{-1}, 16.46 kg ha^{-1} and 137.70 g ha^{-1}, respectively. The minimum total N, P, K, S and B uptake by plants was recorded with $S_0B_0P_0$ with corresponding values of 130.70 kg ha^{-1} and 130.83 kg ha^{-1}, 9.27 kg ha^{-1} and 9.32 kg ha^{-1}, 72.85 kg ha^{-1} and 72.48 kg ha^{-1}, 8.59 kg ha^{-1} and 8.41 kg ha^{-1}, and 42.65 g ha^{-1} and 43.92 g ha^{-1} during 2016 and 2017, respectively, while the pooled data had 130.77 kg ha^{-1}, 9.30 kg ha^{-1}, 72.67 kg ha^{-1}, 8.50 kg ha^{-1} and 43.29 g ha^{-1}, respectively. The treatment combination $S_2B_2P_1$ was observed to have significantly higher total N, P, K, S and B uptake by plants as compared to other treatment combinations. It was observed that the total uptake of P by plants with treatment $S_2B_1P_1$ was significantly higher than treatment $S_2B_2P_0$, while $S_1B_2P_1$ was at par with $S_2B_0P_0$, $S_0B_2P_1$ was at par with $S_1B_0P_0$, and $S_0B_0P_1$ at par with $S_0B_1P_0$.

Longkumer *et al.* (2017) and Ravi *et al.* (2017) observed significant increase in N, P, K, S and B uptake by soybean with sulphur and boron application. Sentimenla *et al.* (2012) revealed that N, P, K and B uptake by soybean was significantly increased with different levels of phosphorus and boron fertilization either alone or in combination. Dhage *et al.* (2008) revealed that dual inoculation of *rhizobium* + PSB resulted in higher uptake of N, P and K by soybean even in the absence of chemical fertilizers. Sandeep *et al.* (2008) unveiled that inoculation with PSM significantly increased the uptake of N and P. Well developed root system, higher matter production, seed and stover yield as a result of improved nutrient availability might be responsible for higher nutrient uptake by soybean.

4.5. Effect on quality attributes

The results on the effect of sulphur, boron and phosphorus solubilizing biofertilizer on quality attributes *viz.* protein content and yield and oil content and yield in seeds are presented below:

4.5.1. Effect on protein content and yield

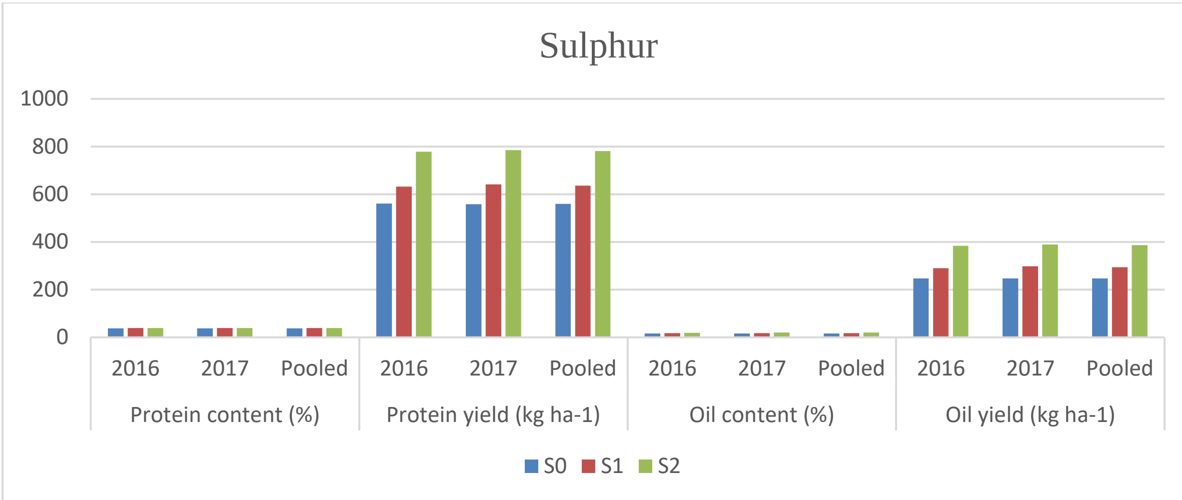
4.5.1.1. Effect of sulphur on protein content and yield

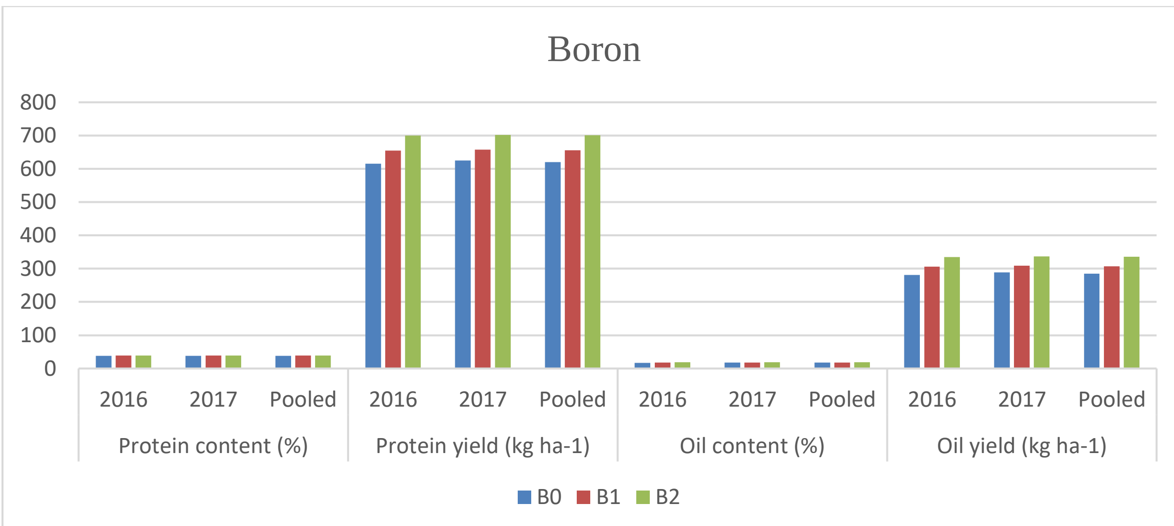
The effect of sulphur on protein content and yield has been presented in Table 4.5 (a) and Fig. 9. It has been observed that the application of sulphur has a significant influence on the protein content in soybean. It was evident that with increased level of sulphur application up to 40 kg S ha^{-1} slightly increases the protein content. The maximum protein content was observed with S_2 (40 kg S ha^{-1}) which recorded 39.62% and 39.64% during 2016 and 2017, respectively while in the pooled it had 39.63%. The lowest protein content was observed with S_0 which recorded 37.31% and 37.22% during 2016 and 2017, respectively while in the pooled data it was 37.26%.

As evident from Table 4.5 (a), the maximum protein yield was observed with S_2 which recorded 777.72 kg ha^{-1} and 784 kg ha^{-1} with pooled data as 781.33 kg ha^{-1} during 2016 and 2017, respectively. The lowest protein yield was observed with S_0 which recorded 560.62 kg ha^{-1} and 558.48 kg ha^{-1} with pooled data as 559.55 kg ha^{-1} during 2016 and 2017, respectively. Application of sulphur was found to have a significant effect on the protein yield. It has been revealed that S_2 was significant over S_1 and S_0.

Table 4.5 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on protein content and oil content, protein yield and oil yield of soybean

Treatments	**Protein content (%)**			**Protein yield (kg ha^{-1})**			**Oil content (%)**			**Oil yield (kg ha^{-1})**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	37.31	37.22	37.26	560.62	558.48	559.55	16.42	16.47	16.45	246.83	247.28	247.05
S_1	38.70	38.65	38.67	631.61	641.02	636.32	17.77	17.97	17.87	290.21	298.15	294.18
S_2	39.62	39.64	39.63	777.72	784.94	781.33	19.53	19.63	19.58	383.87	389.20	386.53
SEm±	***0.40***	***0.43***	***0.29***	***0.86***	***0.96***	***0.64***	***0.41***	***0.29***	***0.25***	***0.73***	***0.88***	***0.57***
CD(P=0.05)	***1.55***	***1.70***	***0.96***	***3.36***	***3.76***	***2.10***	***1.59***	***1.13***	***0.81***	***2.88***	***3.44***	***1.86***
B_0	38.23	38.22	38.23	615.09	625.19	620.14	17.38	17.58	17.48	280.73	289.02	284.88
B_1	38.59	38.58	38.59	654.54	657.24	655.89	17.92	18.04	17.98	305.70	308.76	307.23
B_2	38.80	38.70	38.75	700.31	702.01	701.16	18.41	18.45	18.43	334.47	336.84	335.66
SEm±	***0.25***	***0.28***	***0.19***	***0.66***	***1.11***	***0.65***	***0.28***	***0.29***	***0.20***	***0.82***	***1.39***	***0.81***
CD(P=0.05)	***NS***	***NS***	***NS***	***2.04***	***3.42***	***1.89***	***NS***	***NS***	***NS***	***2.52***	***4.29***	***2.36***
P_0	38.42	38.40	38.41	647.91	651.06	649.48	17.84	17.96	17.90	302.56	306.22	304.39
P_1	38.66	38.60	38.63	665.39	671.90	668.65	17.97	18.09	18.03	311.38	316.86	314.12
SEm±	***0.09***	***0.24***	***0.13***	***0.92***	***0.82***	***0.62***	***0.18***	***0.14***	***0.11***	***0.73***	***0.96***	***0.60***
CD(P=0.05)	***NS***	***NS***	***NS***	***2.74***	***2.44***	***1.77***	***NS***	***NS***	***NS***	***2.16***	***2.85***	***1.73***





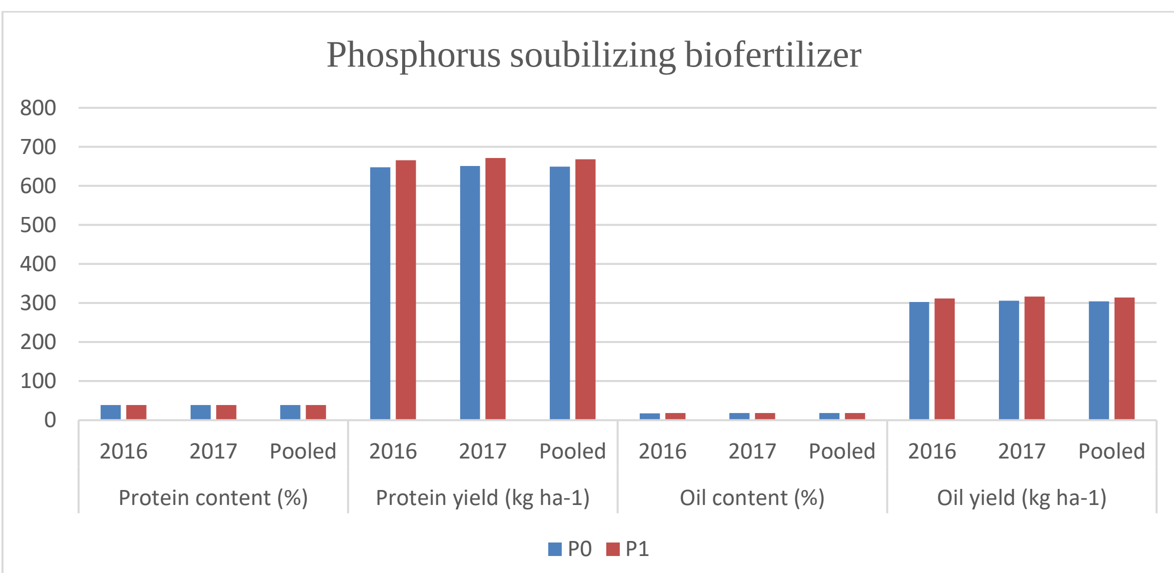


Fig: 9: Effect of sulfur, boron and phosphorus solubilizing biofertilizeron protein content and oil content, protein yield and oil yield of soybean

The improved protein content and yield might be due to synthesis of sulphur containing amino acids induced by sulphur application and finally its conversion into protein (Biswas *et al.*, 2006). The present findings of the study on protein content and protein yield are in conformity with the observations of Lakshman *et al.* (2015).

4.5.1.2. Effect of boron on protein content and yield

Table 4.5 (a) and Fig. 9 revealed the results on the effect of boron on protein content and yield. The highest protein content was observed with B_2 which recorded 38.80% and 38.70% while the lowest was observed with B_0 which recorded 38%.23 and 38.22% during 2016 and 2017, respectively. In the pooled data, B_2 recorded an average protein content of 38.75% while B_0 recorded 38.23%. It has been observed that application of boron did not have any significant effect on the protein content in soybean.

The results revealed that boron fertilization had a significant effect on the protein yield in soybean. The maximum protein yield was observed with B_2 which recorded 700.31 kg ha^{-1} and 702.01 kg ha^{-1} whereas B_0 recorded the lowest protein yield with 615.09 kg ha^{-1} and 625.19 kg ha^{-1} during 2016 and 2017, respectively. In the pooled data, B_2 recorded an average protein yield of 701.01 kg ha^{-1} while B_0 recorded 620.14 kg ha^{-1}. It was observed that B_2 level of boron application was significant over B_1 and B_0.

The results are in consistence with the observations of Ram *et al.* (2014) who also reported that boron application does not have any significant influence on the oil content in soybean. The significant increased in the protein yield could be due to increased in the seed yield with boron application.

4.5.1.3. Effect of phosphorus solubilizing biofertilizer on protein content and yield

Table 4.5 (a) and Fig. 9 presented the effect of phosphorus solubilizing biofertilizer on protein content and yield. From the results obtained, it was apparent that phosphorus solubilizing biofertilizer did not have any significant influence on protein content. It has been revealed that application of phosphorus solubilizing biofertilizer (P_1) as seed treatment recorded slightly higher protein content as 38.66% and 38.60% as compared to P_0 which recorded 38.42% and 38.40% during 2016 and 2017, respectively. In the pooled data, P_1 have an average protein content of 38.63% while P_0 have 38.41%.

The results indicated that seed treatment with phosphorus solubilizing biofertilizer (P_1) recorded significantly higher protein yield which recorded 665.39 kg ha^{-1} and 671.90 kg ha^{-1} as compared to P_0 which recorded 647.91 kg ha^{-1} and 651.06 kg ha^{-1} during 2016 and 2017, respectively. In the pooled data, P_1 recorded an average protein yield of 668.65 kg ha^{-1} while P_0 was 649.48 kg ha^{-1}. The significant increased in the protein yield could be due to increased in the seed yield with phosphorus solubilizing biofertilizer (P_1) application.

The increased protein yield could be attributed to the fact that phosphorus solubilizing biofertilizer inoculation increased the seed yield and that the protein yield is directly related with seed yield. Similar results on protein yield with PSB inoculation has also been reported by Devi *et al.* (2013) and Diep *et al.* (2016).

4.5.1.4. Effect of sulphur and boron interaction on protein content and yield

The result on the effects of sulphur and boron interaction on protein content and yield has been shown in Table 4.5 (b). The results revealed that sulphur and boron interaction did not have any significant influence on the protein content in soybean. The maximum protein content was observed when S_2B_2 was applied which recorded 39.83% and 39.77% with pooled data as 39.80% during 2016 and 2017, respectively. The lowest protein content was observed when no sulphur and boron were applied *i.e.*, S_0B_0 which recorded 37.17% and 37.11% with pooled data as 37.14% during 2016 and 2017, respectively.

The results indicated that application of sulphur along with boron have a significant influence on the protein yield of soybean. The maximum protein yield was observed with S_2B_2 which obtained 844.27 kg ha^{-1} and 842.03 kg ha^{-1} with pooled data as 843.15 kg ha^{-1} during 2016 and 2017, respectively. The lowest protein yield was observed with S_2B_2 which obtained 532.36 kg ha^{-1} and 528.76 kg ha^{-1} with pooled data as 530.56 kg ha^{-1} during 2016 and 2017, respectively. It was observed that increasing the boron fertilization at all levels of sulphur application significantly increased protein yield than application of sulphur alone. Among the different treatments, the interaction effect of S_2B_2 on protein yield was found to be significantly higher.

Sarker *et al.* (2002) also observed that interaction between sulphur and boron did not have any significant influence on protein and oil content in soybean. However, the significant increased in the protein yield might be due to increased seed yield with sulphur and boron fertilization and also protein yield calculation is directly link to seed yield.

Table 4.5 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on protein content and oil content, protein yield and oil yield of soybean

Treatments	Protein content (%)			Protein yield (kg ha^{-1})			Oil content (%)			Oil yield (kg ha^{-1})		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0B_0	37.17	37.11	37.14	532.36	528.76	530.56	16.20	16.25	16.22	231.98	231.60	231.79
S_0B_1	37.26	37.26	37.26	566.91	562.82	564.87	16.32	16.42	16.37	248.24	247.95	248.09
S_0B_2	37.49	37.28	37.39	582.58	583.85	583.22	16.75	16.75	16.75	260.26	262.30	261.28
S_1B_0	38.20	38.17	38.18	596.40	609.46	602.93	17.20	17.38	17.29	268.53	277.50	273.01
S_1B_1	38.79	38.73	38.76	624.35	633.46	628.90	17.76	18.14	17.95	285.89	296.67	291.28
S_1B_2	39.10	39.04	39.07	674.07	680.15	677.11	18.34	18.39	18.36	316.21	320.27	318.24
S_2B_0	39.32	39.39	39.36	716.51	737.36	726.94	18.75	19.12	18.94	341.68	357.97	349.83
S_2B_1	39.71	39.76	39.73	772.36	775.43	773.90	19.69	19.57	19.63	382.98	381.66	382.32
S_2B_2	39.83	39.77	39.80	844.27	842.03	843.15	20.14	20.21	20.18	426.95	427.96	427.45
SEm±	***0.43***	***0.49***	***0.32***	***1.15***	***1.92***	***1.12***	***0.49***	***0.50***	***0.35***	***1.41***	***2.41***	***1.40***
CD(P=0.05)	***NS***	***NS***	***NS***	***3.53***	***5.92***	***3.27***	***NS***	***NS***	***NS***	***4.36***	***7.44***	***4.08***
S_0P_0	37.22	37.15	37.19	556.94	553.78	555.36	16.37	16.38	16.37	244.98	244.21	244.60
S_0P_1	37.40	37.28	37.34	564.29	563.18	563.74	16.48	16.56	16.52	248.67	250.35	249.51
S_1P_0	38.50	38.43	38.47	622.71	631.33	627.02	17.65	17.93	17.79	285.55	294.69	290.12
S_1P_1	38.89	38.86	38.88	640.51	650.72	645.62	17.89	18.00	17.94	294.87	301.61	298.24
S_2P_0	39.54	39.60	39.57	764.07	768.07	766.07	19.50	19.56	19.53	377.14	379.77	378.45
S_2P_1	39.70	39.67	39.68	791.36	801.81	796.59	19.56	19.70	19.63	390.61	398.62	394.62
SEm±	***0.16***	***0.41***	***0.22***	***1.59***	***1.42***	***1.07***	***0.31***	***0.24***	***0.19***	***1.26***	***1.66***	***1.04***
CD(P=0.05)	***NS***	***NS***	***NS***	***4.74***	***4.22***	***3.06***	***NS***	***NS***	***NS***	***3.73***	***4.94***	***2.99***
B_0P_0	38.07	38.08	38.07	608.21	617.46	612.84	17.42	17.43	17.43	279.46	283.93	281.69
B_0P_1	38.39	38.36	38.38	621.97	632.92	627.45	17.34	17.73	17.54	282.00	294.12	288.06
B_1P_0	38.52	38.52	38.52	647.98	650.04	649.01	17.79	18.10	17.95	300.84	306.88	303.86
B_1P_1	38.66	38.65	38.65	661.10	664.44	662.77	18.06	17.98	18.02	310.56	310.64	310.60
B_2P_0	38.67	38.59	38.63	687.52	685.66	686.59	18.30	18.34	18.32	327.37	327.86	327.61
B_2P_1	38.93	38.80	38.87	713.09	718.35	715.72	18.52	18.55	18.54	341.57	345.82	343.70
SEm±	***0.16***	***0.41***	***0.22***	***1.59***	***1.42***	***1.07***	***0.31***	***0.24***	***0.19***	***1.26***	***1.66***	***1.04***
CD(P=0.05)	***NS***	***NS***	***NS***	***4.74***	***4.22***	***3.06***	***NS***	***NS***	***NS***	***3.73***	***4.94***	***2.99***

4.5.1.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on protein content and yield

The interaction effect of sulphur and phosphorus solubilizing biofertilizer on protein content and yield has been presented in Table 4.5 (b). The results revealed that the interaction between sulphur and phosphorus solubilizing biofertilizer have no significant effect on protein content. The maximum protein content was observed with treatment S_2P_1 having 39.70% and 39.67% with pooled data as 39.68% whereas, the lowest was observed with S_0P_0 which recorded 37.22% and 37.15% and pooled data of 37.19% during 2016 and 2017, respectively.

The protein yield was found to be significantly influenced by combined application of sulphur with phosphorus solubilizing biofertilizer. From the results, it was apparent that the maximum protein yield was obtained from treatment S_2P_1 which recorded 791.36 kg ha^{-1} and 801.81 kg ha^{-1} with pooled data of 796.59 kg ha^{-1} during 2016 and 2017, respectively. The lowest was observed with zero level of sulphur and phosphorus solubilizing biofertilizer application *i.e.*, S_0P_0 which recorded 556.94 kg ha^{-1} and 553.78 kg ha^{-1} with pooled data of 555.36 kg ha^{-1} during 2016 and 2017, respectively. There was significant difference among the treatment, however, the protein yield obtained with S_2P_1 was found to be significantly higher.

The significant increased in the protein yield might be due to improved plant nutrition through sulphur and phosphorus solubilizing biofertilizer application resulting in higher seed yield, moreover, the final protein yield was calculated from the seed yield.

4.5.1.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on protein content and yield

Table 4.5 (b) showed the effect of boron and phosphorus solubilizing biofertilizer interaction on protein content and yield. The interaction effect on protein content between boron and phosphorus solubilizing biofertilizer was observed to be non significant. The highest protein content was observed with B_2P_1 having 38.93% and 38.80% with pooled data of 38.87% while B_0P_0 was the lowest with 38.07% and 38.08% and pooled data of 38.07% during 2016 and 2017, respectively.

From the results obtained, it became evident that application of boron up to 2 kg B ha^{-1} along with phosphorus solubilizing biofertilizer as seed treatment significantly increased the protein yield as compared to application of boron alone. The maximum protein yield was obtained when B_2P_1 was applied which recorded 713.09 kg ha^{-1} and 718.35 kg ha^{-1} with pooled data of 715.72 kg ha^{-1} in 2016 and 2017, respectively. The lowest protein yield was obtained with zero level of boron and phosphorus solubilizing biofertilizer *i.e.*, B_0P_0 were applied which obtained a protein yield of 608.21 kg ha^{-1} and 617.46 kg ha^{-1} with pooled data of 612.84 kg ha^{-1} in 2016 and 2017, respectively. Among the different treatments, the interaction effect of B_2P_1 was found to be significantly higher.

The significant increased in protein yield might be due to the fact that the calculation of protein yield was based on seed yield and also the fact that seed yield was significantly increased with boron fertilization along with phosphorus solubilizing biofertilizer as seed treatment.

4.5.1.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on protein content and yield

The interaction effect between sulphur, boron and phosphorus solubilizing biofertilizer on protein content and yield has been presented in Table 4.5 (c). The results showed that the protein content was not significantly influenced by the interaction between sulphur, boron and phosphorus solubilizing biofertilizer. However, a gradual increased in the protein content was observed with increasing levels of sulphur and boron fertilization along with phosphorus solubilizing biofertilizer as seed treatment. The highest protein content was obtained from treatment $S_2B_2P_1$ which recorded 39.90% and 39.81% with pooled data of 39.86% whereas $S_0B_0P_0$ recorded the lowet with 37.11% and 37.02% with pooled data of 37.06% in 2016 and 2017, respectively

From the result, it was evident that interaction between sulphur, boron and phosphorus solubilizing biofertilizer had significant influence on the protein yield. The protein yield was significantly increased when the levels of sulphur and boron were increased up to 40 kg S ha^{-1} and 2 kg B ha^{-1}, respectively along with phosphorus solubilizing biofertilizer as seed treatment. The maximum protein yield was obtained with $S_2B_2P_1$ which recorded 866.31 kg ha^{-1} and 868.41 kg ha^{-1} with pooled data of 867.36 kg ha^{-1} while the lowest was obtained with $S_0B_0P_0$ (control) which recorded 528.69 kg ha^{-1} and 524.55 kg ha^{-1} with pooled data of 526.62 kg ha^{-1} in 2016 and 2017, respectively. There was significant difference among the treatment, however, the interaction effect of $S_2B_2P_1$ on protein yield was observed to be significantly higher.

Table 4.5 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on protein content and oil content, protein yield and oil yield of soybean

Treatments	Protein content (%)			Protein yield (kg ha^{-1})			Oil content (%)			Oil yield (kg ha^{-1})		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
$S_0B_0P_0$	37.11	37.02	37.06	528.69	524.55	526.62	16.15	16.18	16.17	230.15	229.26	229.70
$S_0B_0P_1$	37.23	37.19	37.21	536.03	532.97	534.50	16.24	16.32	16.28	233.81	233.93	233.87
$S_0B_1P_0$	37.23	37.21	37.22	564.01	555.26	559.63	16.32	16.35	16.33	247.24	243.93	245.58
$S_0B_1P_1$	37.29	37.31	37.30	569.81	570.39	570.10	16.31	16.48	16.40	249.23	251.97	250.60
$S_0B_2P_0$	37.31	37.23	37.27	578.11	581.52	579.82	16.62	16.61	16.62	257.56	259.45	258.50
$S_0B_2P_1$	37.67	37.33	37.50	587.05	586.18	586.61	16.87	16.89	16.88	262.95	265.14	264.05
$S_1B_0P_0$	37.88	37.90	37.89	589.75	602.42	596.09	17.23	17.18	17.20	268.25	273.05	270.65
$S_1B_0P_1$	38.52	38.44	38.48	603.05	616.50	609.78	17.17	17.58	17.38	268.81	281.94	275.37
$S_1B_1P_0$	38.67	38.58	38.63	616.14	631.73	623.93	17.52	18.35	17.93	279.10	300.28	289.69
$S_1B_1P_1$	38.92	38.88	38.90	632.56	635.19	633.87	18.01	17.94	17.97	292.68	293.06	292.87
$S_1B_2P_0$	38.96	38.82	38.89	662.23	659.82	661.03	18.20	18.28	18.24	309.30	310.73	310.02
$S_1B_2P_1$	39.23	39.27	39.25	685.92	700.47	693.19	18.48	18.49	18.49	323.11	329.81	326.46
$S_2B_0P_0$	39.23	39.31	39.27	706.18	725.42	715.80	18.89	18.94	18.91	339.98	349.47	344.72
$S_2B_0P_1$	39.42	39.46	39.44	726.84	749.30	738.07	18.62	19.30	18.96	343.39	366.47	354.93
$S_2B_1P_0$	39.65	39.77	39.71	763.80	763.14	763.47	19.53	19.62	19.57	376.18	376.45	376.32
$S_2B_1P_1$	39.77	39.75	39.76	780.93	787.72	784.32	19.85	19.52	19.69	389.78	386.88	388.33
$S_2B_2P_0$	39.75	39.73	39.74	822.24	815.64	818.94	20.07	20.14	20.11	415.25	413.40	414.32
$S_2B_2P_1$	39.90	39.81	39.86	866.31	868.41	867.36	20.20	20.29	20.25	438.66	442.52	440.59
SEm±	***0.27***	***0.72***	***0.38***	***2.76***	***2.46***	***1.85***	***0.53***	***0.41***	***0.34***	***2.18***	***2.88***	***1.81***
CD(P=0.05)	***NS***	***NS***	***NS***	***8.21***	***7.31***	***5.30***	***NS***	***NS***	***NS***	***6.47***	***8.56***	***5.18***

Though the interaction effect on protein content was non-significant, the significant increased in protein yield might be due to the fact that the calculation on protein yield was based on seed yield. Moreover, improved plant nutrition through sulphur, boron and phosphorus solubilizing biofertilizer application had resulted in higher seed yield. Similar results on protein yield by soybean had been reported by Devi *et al.* (2013) and Diep *et al.* (2016).

4.5.2. Effect on oil content and yield

4.5.2.1. Effect of sulphur on oil content and yield

Table 4.5 (a) presented the result on the effect of sulphur on oil content and yield. It has been observed that sulphur fertilization up to 40 kg S ha^{-1} significantly increases the oil content and oil yield in soybean. The maximum oil content and yield has been observed where S_2 (40 kg S ha^{-1}) was applied which recorded 19.53% and 19.63% with pooled data of 19.58%, and 383.87 kg ha^{-1} and 389.20 kg ha^{-1} with pooled data of 386.53 kg ha^{-1} during 2016 and 2017, respectively. The lowest oil content and yield was obtained in plots where no sulphur was applied *i.e.*, S_0 which recorded 16.42% and 16.47% with pooled data of 16.45%, 246.83 kg ha^{-1} and 247.28 kg ha^{-1} and pooled data of 247.05 kg ha^{-1} during 2016 and 2017, respectively. There was significant difference among the levels of sulphur and S_2 was observed to be significantly higher than S_1 and S_0.

The improved oil content and oil yield might be due to increased S uptake by plants which is required for biosynthesis of oil. Ganeshamurthy (1996), Farhad *et al.* (2010) and Choudhary *et al.* (2014) also observed that sulphur application significantly increases the oil content in soybean. Similar results on oil content and oil yield in soybean was also observed by Chauhan *et al*. (2013) and Lakshman *et al*. (2015).

4.5.2.2. Effect of boron on oil content and yield

The result on the effect of boron on oil content and yield has been presented in Table 4.5 (a). The effect of boron fertilization on the oil content was observed to be non significant. The results indicated that application of B_1 (1 kg B ha^{-1}) and B_2 (2 kg B ha^{-1}) obtained slightly higher oil content than B_0 (0 kg B ha^{-1}). The maximum oil content was observed where B_2 was applied which recorded 18.41% and 18.45% with pooled data of 18.43% whereas B_0 recorded the lowest with 17.38% and 17.58% with pooled data of 17.48%.

The oil yield was found to be significantly influenced by boron fertilization. The maximum oil yield was obtained with B_2 (2 kg B ha^{-1}) which recorded 334.47 kg ha^{-1} and 336.84 kg ha^{-1} with a pooled data of 335.66 kg ha^{-1} whereas, the lowest oil yield was obtained with B_0 which recorded 280.73 kg ha^{-1} and 289.02 kg ha^{-1} with pooled data of 284.88 kg ha^{-1} during 2016 and 2017, respectively. Significant difference was observed among the levels of boron, however, B_2 was observed to be significantly higher than B_1 and B_0.

The findings are in accordance with the findings of Ismail *et al.* (2013) who reported that oil content was not influenced by boron application however, the oil yield were significantly increased. The role of B on biosynthesis of oil and fatty acids might be responsible for the increased oil yield in oilseeds (Malewar *et al*., 2001). Yadav *et al*. (2016) also observed increase in oil content with B application.

4.5.2.3. Effect of phosphorus solubilizing biofertilizer on oil content and yield

Table 4.5 (a) presented the effect of phosphorus solubilizing biofertilizer on oil content and yield in soybean. It has been revealed that application of phosphorus solubilizing biofertilizer did not have any significant influence on the oil content. However, application of P_1 recorded a slightly higher oil content of 17.97% and 18.09% with pooled data of 18.03% as compared to P_0 which was 17.84% and 17.96% with pooled data of 17.90% during 2016 and 2017, respectively.

The results revealed that phosphorus solubilizing biofertilizer have a significant influence on the oil yield of soybean. It was observed that P_1 recorded higher oil yield which obtained 311.38 kg ha^{-1} and 316.86 kg ha^{-1} with pooled data of 314.12 kg ha^{-1} as compared to P_0 which obtained 302.56 kg ha^{-1} and 306.22 kg ha^{-1} with pooled data of 304.39 kg ha^{-1} in 2016 and 2017, respectively. Similar results on oil content and oil yield in soybean with application of PSB has been reported by Dhage *et al.* (2008) and Devi *et al.* (2018). The significant increased in the oil yield might be due to the fact that oil yield calculation was based on seed yield where the seed yield was increased significantly with application of phosphorus solubilizing biofertilizer.

4.5.2.4. Effect of sulphur and boron interaction on oil content and yield

The interaction effect of sulphur and boron on the oil content and yield has been presented in Table 4.5 (b). It was observed that the interaction between sulphur and boron did not have any significant effect on the oil content in soybean. The maximum oil content was obtained with S_2B_2 which was 20.14% and 20.21% with pooled data of 20.18% whereas, the lowest was observed with 16.20% and 16.25% with pooled data of 16.22% during 2016 and 2017, respectively.

As evident from the results presented in Table 4.5 (b), the interaction between sulphur and boron was observed to have a significant influence on the oil yield. It has been apparent from the results that increasing the boron fertilization up to 2 kg B ha^{-1} at all levels of sulphur significantly increased the oil yield. The maximum oil yield was obtained from S_2B_2 which recorded 426.95 kg ha^{-1} and 427.96 kg ha^{-1} with pooled data of 427.45 kg ha^{-1} while S_0B_0 recorded the lowest with 231.98 kg ha^{-1} and 231.60 kg ha^{-1} and pooled data of 231.79 kg ha^{-1} during 2016 and 2017, respectively. Significantly difference of interaction effect on oil yield was observed among the different treatment, however, S_2B_2 was found to have significantly higher oil yield. Sarker *et al.* (2002) also recorded that sulphur and boron interaction did not have any significant effect on oil content in soybean. However, the significant increased in oil yield could be linked to the increased seed yield with sulphur and boron fertilization. Similar results on oil content with application of sulphur and boron Ram *et al.* (2014) and Longkumer *et al.* (2014).

4.5.2.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on oil content and yield

Table 4.5 (b) presented that effect of sulphur and phosphorus solubilizing biofertilizer interaction on oil content and yield. The effect of interaction between sulphur and phosphorus solubilizing biofertilizer was observed to be non significant on the oil content. The maximum oil content was obtained where S_2P_1 was applied which recorded 19.56% and 19.70% with a pooled data of 19.63% whereas the lowest was observed with S_0P_0 which recorded 16.37% and 16.38% with a pooled data of 16.37% in 2016 and 2017, respectively.

The results revealed that the highest oil yield was obtained when S_2P_1 was applied which recorded 390.61 kg ha^{-1} and 398.62 kg ha^{-1} with pooled data of 394.62 kg ha^{-1} while the lowest oil yield was obtained with S_0P_0 which recorded 244.98 kg ha^{-1} and 244.21 kg ha^{-1} with a pooled data of 244.60 kg ha^{-1} during 2016 and 2017, respectively. It has been revealed that increasing the sulphur fertilization up to 40 kg S ha^{-1} along with phosphorus solubilizing biofertilizer significantly increased the oil yield. The interaction effect of S_2P_1 on the oil yield was found to be significantly higher than other treatment combinations. Majumdar *et al.* (2001) observed similar oil yield in soybean with combined application of phosphorus and sulphur which shows the importance of phosphorus and sulphur in seed quality improvement of soybean in soils deficient in these two nutrients.

4.5.2.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on oil content and yield

The effect of boron and phosphorus solubilizing biofertilizer interaction on oil content and yield has been shown in Table 4.5 (b). The results revealed that the maximum oil content was observed with B_2P_1 which recorded 18.52% and 18.55% with a pooled data of 18.54% while the lowest was observed with B_0P_0 which recorded 17.42% and 17.43% with pooled data of 17.43% in 2016 and 2017, respectively. The interaction effect between boron and phosphorus solubilizing biofertilizer on the oil content was found to be non significant.

It has been revealed from the results that application of boron up to 2 kg B ha^{-1} along with phosphorus solubilizing biofertilizer significantly increased the oil yield in soybean. The maximum oil yield was obtained with B_2P_1 which recorded 341.57% and 345.82% with pooled data of 343.70% whereas the lowest was observed with B_0P_0 which recorded 279.46% and 283.93% and pooled data of 281.69% in 2016 and 2017, respectively. The results indicated significant interaction effect on the oil yield between boron and phosphorus solubilizing biofertilizer. However, the interaction effect of B_2P_1 on oil yield was significantly higher than other treatment combinations. The significant increased in the oil yield might be due to the fact that oil yield calculation was based on seed yield where the seed yield was increased significantly with application of boron and phosphorus solubilizing biofertilizer.

4.5.2.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on oil content and yield

Table 4.5 (c) presented the effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on oil content and yield. The interaction between the three factors on the oil content was found to be non significant. The maximum oil content was obtained with $S_2B_2P_1$ which recorded 20.20% and 20.29% with pooled data of 20.25% while the lowest was obtained with $S_0B_0P_0$ which recorded 16.15% and 16.18% with pooled data of 16.17% during 2016 and 2017.

As evident from the results presented in Table 4.5 (c), the interaction between sulphur, boron and phosphorus solubilizing biofertilizer have a significant effect on the oil yield in soybean. The maximum oil yield was obtained where $S_2B_2P_1$ was applied which recorded 438.66 kg ha^{-1} and 442.52 kg ha^{-1} with pooled data as 440.59 kgha^{-1} whereas the lowest was obtained with $S_0B_0P_0$ which recorded 230.15 kg ha^{-1} and 229.26 kg ha^{-1} with a pooled data of 229.70 kg ha^{-1} in 2016 and 2017, respectively. It was observed that increasing the level of boron fertilization at all levels of sulphur along with phosphorus solubilizing biofertilizer significantly increased the oil yield. The interaction effect of $S_2B_2P_1$ on oil yield was found to be significantly higher than other treatment combinations.

The increased oil yield might be due to the improved nutrient availability resulting in higher seed yield which have a direct influence on the oil yield. Similar results on oil content with application of sulphur and boron Ram *et al.* (2014) and Longkumer *et al.* (2014). Dhage *et al.* (2008) and Devi *et al.* (2018) also observed similar results on oil content and oil yield in soybean with application of PSB.

4.6. Effect on soil fertility after harvest

The results on the effect of sulphur, boron and phosphorus solubilizing biofertilizer on the soil fertility after harvest are discussed below:

4.6.1. Effect on pH, organic carbon, electrical conductivity (EC) and cation exchange capacity (CEC) of soil after harvest

4.6.1.1. Effect of sulphur on pH, organic carbon, electrical conductivity (EC) and cation exchange capacity (CEC) of soil after harvest

The results on soil pH, organic carbon, electrical conductivity (EC) and cation exchange capacity (CEC) by different treatments have been presented in Table 4.6.1 (a).

It was evident from results that application of sulphur did not have any significant effect on the soil pH. However, it was observed that with increasing dose of sulphur application, there was a slight increase in the soil acidity. The highest soil pH was observed in plots receiving zero sulphur (S_0) which recorded 5.47 and 5.46 with pooled data of 5.47 while the lowest pH was observed with S_2 (40 kg S ha^{-1}) which recorded 5.36 and 5.34 with pooled data of 5.35 during 2016 and 2017, respectively.

As evident from the Table 4.6.1 (a), sulphur fertilization did not have any significant influence on the soil organic carbon content after harvest. The organic carbon content in soil after harvest was highest in plots receiving S_2 (40 kg S ha^{-1}) which recorded 1.28% both in 2016 and 2017, respectively with pooled data of 1.28%, whereas the lowest was observed in plots receiving S_0 with 0.93% both in 2016 and 2017 and in pooled data.

Table 4.6.1 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on pH, organic carbon, EC and CEC of soil after harvest

Treatments	**pH**			**Organic carbon (%)**			**EC (dS m^{-1})**			**CEC {cmol (p)kg^{-1}}**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	5.47	5.46	5.47	0.93	0.93	0.93	0.18	0.18	0.18	15.17	15.38	15.28
S_1	5.44	5.42	5.43	1.13	1.17	1.15	0.17	0.17	0.17	15.96	16.08	16.02
S_2	5.36	5.34	5.35	1.28	1.28	1.28	0.17	0.16	0.16	16.73	16.70	16.72
SEm±	***0.05***	***0.04***	***0.03***	***0.07***	***0.07***	***0.05***	***0.004***	***0.004***	***0.003***	***0.36***	***0.30***	***0.23***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
B_0	5.44	5.42	5.43	1.05	1.04	1.04	0.18	0.17	0.18	15.30	15.53	15.41
B_1	5.42	5.41	5.41	1.12	1.13	1.13	0.17	0.17	0.17	15.97	15.86	15.91
B_2	5.41	5.39	5.40	1.18	1.20	1.19	0.17	0.17	0.17	16.61	16.78	16.69
SEm±	***0.02***	***0.03***	***0.02***	***0.05***	***0.05***	***0.04***	***0.003***	***0.002***	***0.002***	***0.35***	***0.34***	***0.24***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
P_0	5.43	5.41	5.42	1.10	1.11	1.11	0.17	0.17	0.17	15.81	15.84	15.83
P_1	5.42	5.40	5.41	1.13	1.13	1.13	0.17	0.17	0.17	16.10	16.27	16.19
SEm±	***0.02***	***0.03***	***0.02***	***0.02***	***0.03***	***0.02***	***0.002***	***0.003***	***0.002***	***0.26***	***0.37***	***0.23***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***

The effect of sulphur application on the electrical conductivity (EC) was found to be non-significant. It was observed that the EC of soil tend to be slightly higher in plots where no sulphur was applied *i.e.*, in control plots. The maximum EC was observed with S_0 which recorded 0.18 dS m^{-1} in 2016 and 2017 and in the pooled data, while the lowest was observed with S_2 with EC value of 0.17 and 0.16 dS m^{-1} and pooled data of 0.16 dS m^{-1} during 2016 and 2017, respectively.

It was apparent from the results that CEC of the soil was not influenced by sulphur fertilization. The maximum CEC was recorded with application of S_2 with CEC value of 16.73 cmol (p^+) kg^{-1} and 16.70 cmol (p^+) kg^{-1} and pooled data of 16.72 cmol (p^+) kg^{-1} whereas, the lowest was obtained from S_0 with 15.17 cmol (p^+) kg^{-1} and 15.38 cmol (p^+) kg^{-1} during 2016 and 2017, respectively and pooled data as 15.28 cmol (p^+) kg^{-1}.

4.6.1.2. Effect of boron on pH, organic carbon, electrical conductivity (EC) and cation exchange capacity (CEC) of soil after harvest

As evident from Table 4.6.1 (a), the application of boron did not have any significant influence on the pH and EC of soil after harvest. The maximum pH of soil was observed with S_0 which recorded 5.44 and 5.42 and pooled data of 5.43 in 2016 and 2017 respectively. The lowest pH was observed with S_2 which recorded 5.41 and 5.40 with pooled data of 5.40 in 2016 and 2017, respectively.

The maximum organic carbon was recorded where B_2 (2 kg B ha^{-1}) was applied which recorded an organic carbon content of 1.18% and 1.20% with pooled data of 1.19% during 2016 and 2017, respectively. The minimum organic carbon content was recorded in plots where no boron was applied *i.e.*, B_0 which recorded 1.05% and 1.04% respectively during 2016 and 2017 with pooled data of

1.04% and 15.47 cmol (p^+) kg^{-1}. The effect of boron fertilization on soil organic carbon was found to be non-significant.

The results obtained revealed that the effect of boron application on EC was non-significant. The maximum EC of soil was observed with S_0 which recorded 0.18 dS m^{-1} and 0.17 dS m^{-1} and pooled data of 0.18 dS m^{-1} in 2016 and 2017, respectively. The lowest EC was observed with S_2 which recorded 0.17 dS m^{-1} in 2016 and 2017 and in the pooled data.

It has been revealed from the results presented in Table 4.6.1 (a) that the CEC of soil after harvest was not significantly influenced with boron fertilization. The maximum CEC was recorded where B_2 (2 kg B ha^{-1}) was applied with CEC of 16.61 cmol (p^+) kg^{-1} and 16.78 cmol (p^+) kg^{-1} and pooled data of 16.69 cmol (p^+) kg^{-1} during 2016 and 2017, respectively. The minimum CEC was recorded in plots where no boron was applied *i.e.*, B_0 which recorded 15.17 cmol (p^+) kg^{-1} and 15.38 cmol (p^+) kg^{-1} with pooled data of 15.28 cmol (p^+) kg^{-1}, respectively during 2016 and 2017.

4.6.1.3. Effect of phosphorus solubilizing biofertilizer on pH, organic carbon, electrical conductivity (EC) and cation exchange capacity (CEC) of soil after harvest

The results presented in Table 4.6.1 (a) revealed that application of phosphorus solubilizing biofertilizer as seed treatment in soybean did not have any significant effect on the soil pH. The application of phosphorus solubilizing biofertilizer (P_1) recorded insignificantly lower pH values of 5.42 and 5.40 with pooled data of 5.41 while P_0 have 5.43 and 5.41 with pooled data of 5.42 during 2016 and 2017, respectively.

It was evident from the results that application of phosphorus solubilizing biofertilizer (P_1) recorded higher organic carbon content of 1.13% both in the year 2016 and 2017 and in pooled data as compared to P_0 which recorded 1.10% and 1.11% with pooled data of 1.11% during 2016 and 2017, respectively. There was not much variations in organic carbon content in soil after harvest with application phosphorus solubilizing biofertilizer and non-significant.

The results revealed that application of phosphorus solubilizing biofertilizer did not have any significant effect on the EC and it was observed to remain constant at 0.17 dS m^{-1} both with P_1 and P_0 in 2016 and 2017.

The CEC of soil after harvest was slightly higher with application of phosphorus solubilizing biofertilizer (P_1) which recorded 16.10 cmol (p^+) kg^{-1} and 16.27 cmol (p^+) kg^{-1} with pooled data of 16.19 cmol (p^+) kg^{-1} as compared to P_0 which recorded 15.81 cmol (p^+) kg^{-1} and 15.84 cmol (p^+) kg^{-1} with pooled data of 15.83 cmol (p^+) kg^{-1} during 2016 and 2017, respectively.

4.6.1.4. Effect of sulphur and boron interaction on pH, organic carbon, electrical conductivity (EC) and cation exchange capacity (CEC) of soil after harvest

The result on the effect of sulphur and boron interaction on soil pH, organic carbon, electrical conductivity (EC) and cation exchange capacity (CEC) after harvest has been presented in Table 4.6.1 (b). The results revealed that the interaction between sulphur and boron did not have any significant influence on the soil pH, organic carbon, electrical conductivity (EC) and cation exchange capacity (CEC) of soil after harvest. There was no significant variation observed in pH with application of increasing levels of sulphur and boron. The maximum pH was obtained in the control plot S_0B_0 which recorded pH of 5.48 and 5.47 with

Table 4.6.1 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on pH, organic carbon, EC and CEC of soil after harvest

Treatments	**pH**			**Organic carbon (%)**			**EC (dS m^{-1})**			**CEC {cmol (p)kg^{-1}}**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0B_0	5.48	5.47	5.48	0.85	0.87	0.86	0.19	0.19	0.19	14.73	14.91	14.82
S_0B_1	5.47	5.46	5.46	0.93	0.89	0.91	0.18	0.19	0.18	14.92	15.18	15.05
S_0B_2	5.46	5.45	5.46	1.00	1.02	1.01	0.18	0.18	0.18	15.88	16.06	15.97
S_1B_0	5.44	5.43	5.44	1.07	1.08	1.07	0.18	0.17	0.17	15.63	15.93	15.78
S_1B_1	5.44	5.41	5.42	1.14	1.20	1.17	0.16	0.16	0.16	16.12	16.03	16.07
S_1B_2	5.43	5.41	5.42	1.19	1.23	1.21	0.17	0.17	0.17	16.15	16.27	16.21
S_2B_0	5.39	5.37	5.38	1.22	1.18	1.20	0.17	0.17	0.17	15.54	15.74	15.64
S_2B_1	5.36	5.35	5.35	1.30	1.31	1.30	0.16	0.16	0.16	16.87	16.36	16.61
S_2B_2	5.33	5.31	5.32	1.34	1.35	1.34	0.16	0.16	0.16	17.80	18.01	17.90
SEm±	***0.04***	***0.05***	***0.03***	***0.08***	***0.09***	***0.06***	***0.005***	***0.004***	***0.003***	***0.60***	***0.59***	***0.42***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
S_0P_0	5.47	5.47	5.47	0.90	0.93	0.91	0.19	0.19	0.19	15.00	15.12	15.06
S_0P_1	5.47	5.45	5.46	0.96	0.92	0.94	0.18	0.18	0.18	15.35	15.64	15.50
S_1P_0	5.44	5.41	5.43	1.12	1.17	1.14	0.17	0.17	0.17	16.08	16.22	16.15
S_1P_1	5.43	5.42	5.43	1.14	1.17	1.16	0.17	0.16	0.17	15.85	15.94	15.89
S_2P_0	5.37	5.36	5.36	1.27	1.25	1.26	0.16	0.16	0.16	16.35	16.18	16.27
S_2P_1	5.35	5.33	5.34	1.30	1.30	1.30	0.17	0.16	0.17	17.12	17.22	17.17
SEm±	***0.04***	***0.05***	***0.03***	***0.03***	***0.05***	***0.03***	***0.004***	***0.005***	***0.003***	***0.46***	***0.64***	***0.39***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
B_0P_0	5.44	5.43	5.44	1.02	1.01	1.02	0.17	0.17	0.17	15.04	15.11	15.07
B_0P_1	5.43	5.41	5.42	1.07	1.07	1.07	0.18	0.17	0.18	15.56	15.95	15.75
B_1P_0	5.42	5.41	5.42	1.13	1.14	1.14	0.17	0.17	0.17	15.91	15.81	15.86
B_1P_1	5.42	5.40	5.41	1.12	1.13	1.12	0.17	0.17	0.17	16.02	15.90	15.96
B_2P_0	5.41	5.40	5.41	1.14	1.19	1.16	0.17	0.17	0.17	16.48	16.61	16.54
B_2P_1	5.40	5.38	5.39	1.21	1.21	1.21	0.17	0.17	0.17	16.73	16.95	16.84
SEm±	***0.04***	***0.05***	***0.03***	***0.03***	***0.05***	***0.03***	***0.004***	***0.005***	***0.003***	***0.46***	***0.64***	***0.39***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***

pooled data as 5.48 during 2016 and 2017, respectively. It was observed that S_2B_2 recorded the lowest pH of 5.33 and 5.31 and pooled data of 5.32 in 2016 and 2017, respectively.

The results revealed that organic carbon was not significantly influenced by the interaction between sulphur and boron. The maximum organic carbon content of soil after harvest was observed with S_2B_2 which recorded 1.34% both during 2016 and 2017, respectively and in pooled data. The lowest organic carbon was obtained in plots receiving S_0B_0 which recorded 0.85% and 0.87%, with pooled data of 0.86%, respectively during 2016 and 2017.

The maximum EC was obtained in the control plot S_0B_0 which recorded an EC of 0.19 dS m^{-1} both in 2016 and 2017 and in the pooled data. It was observed that S_2B_2 recorded the lowest EC of 0.16 dS m^{-1} in 2016 and 2017 and in the pooled data.

The highest CEC of soil after harvest was observed with S_2B_2 which recorded 17.80 cmol (p^+) kg^{-1} and 18.01 cmol (p^+) kg^{-1} and pooled data of 17.90 cmol (p^+) kg^{-1} during 2016 and 2017, respectively. The lowest CEC was obtained in plots receiving S_0B_0 which recorded 14.73 cmol (p^+) kg^{-1} and 14.91 cmol (p^+) kg^{-1} with pooled data 14.82 cmol (p^+) kg^{-1}, respectively during 2016 and 2017.

4.6.1.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on pH, organic carbon, electrical conductivity (EC) and cation exchange capacity (CEC) of soil after harvest

The result on interaction effect on pH, organic carbon, EC and CEC of soil after harvest were presented in Table 4.6.1 (b). It was apparent from the results that S_0P_0 recorded the highest pH 5.47 both in 2016 and 2017 and in the pooled data. It was observed that S_2P_1 recorded the lowest pH 5.35 and 5.33 with pooled data of 5.34 during 2016 and 2017, respectively. The results revealed that increasing the levels of sulphur fertilization along with phosphorus solubilizing biofertilizer application slightly decreased the pH of soil however, it was found to be non-significant.

The highest organic carbon content in soil was observed when treatment S_2P_1 was applied which recorded 1.30% both in 2016 and 2017 and in the pooled while the lowest observed in the control (S_0P_0) which recorded 0.90% and 0.93% in 2016 and 2017, respectively with pooled data of 0.91%. The interaction between sulphur and phosphorus solubilizing biofertilizer was found to be non-significant.

The results revealed that S_0P_0 recorded the highest EC of 0.19 cmol (p^+) kg^{-1} both in 2016 and 2017 and in the pooled data. The treatment S_2P_0 recorded the lowest EC of 0.16 dS m^{-1} in 2016 while in 2017 treatment S_1P_1, S_2P_0 and S_2P_1 recorded the lowest EC of 0.16 dS m^{-1}. In pooled data S_2P_0 recorded the lowest EC with 0.16 dS m^{-1}. There was no significant interaction effect between sulphur and phosphorus solubilizing biofertilizer on the soil EC.

As evident from the results, there was no significant interaction effect between sulphur and phosphorus solubilizing biofertilizer on the soil CEC. The results revealed that S_2P_1 recorded the highest CEC with 17.12 cmol (p^+) kg^{-1} and 17.22 cmol (p^+) kg^{-1} with pooled data of 17.17 cmol (p^+) kg^{-1} during 2016 and 2017, respectively. The lowest CEC was observed with control treatment (S_0P_0) which recorded 15.00 cmol (p^+) kg^{-1} and 15.12 cmol (p^+) kg^{-1} with pooled data as 15.06 cmol (p^+) kg^{-1} during 2016 and 2017, respectively.

4.6.1.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on pH, organic carbon, electrical conductivity (EC) and cation exchange capacity (CEC) of soil after harvest

As evident from Table 4.6.1 (b), the interaction between boron and phosphorus solubilizing biofertilizer interaction did not have any significant influence on the soil pH, OC, EC and CEC after harvest. The maximum pH of 5.44 and 5.43 with pooled data of 5.44 was observed with B_0P_0 (control) while the minimum pH of 5.40 and 5.38 with pooled data of 5.39 was observed with B_2P_1 during 2016 and 2017, respectively.

The highest organic carbon content of 1.21% was observed with B_2P_1 during 2016 and 2017, respectively and in the pooled data, whereas the lowest was observed with B_0P_0 which recorded 1.02% and 1.01% in 2016 and 2017 with pooled data of 1.02%. It was revealed that increased level of boron fertilization along with application of phosphorus solubilizing biofertilizer as seed treatment slightly increased the organic carbon content in soil after harvest. However, the increased was observed to be non-significant.

The EC was observed to remain constant at 0.17 dS m^{-1} except with B_0P_1 which recorded 0.17 dS m^{-1} and 0.18 dS m^{-1} with pooled data of 0.18 cmol (p^+) kg^{-1} during 2016 and 2017, respectively.

The highest CEC was observed with B_2P_1 which recorded 16.73 cmol (p^+) kg^{-1} and 16.95 cmol (p^+) kg^{-1} with pooled data of 16.84 cmol (p^+) kg^{-1} and B_0P_0 obtained the lowest with 15.04 cmol (p^+) kg^{-1} and 15.11 cmol (p^+) kg^{-1} with pooled data of 15.07 cmol (p^+) kg^{-1} during 2016 and 2017, respectively. No significant variations were observed among the different treatment combinations.

4.6.1.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on pH, organic carbon, electrical conductivity (EC) and cation exchange capacity (CEC) of soil after harvest

Table 4.6.1 (c) presented the interaction effect of sulphur, boron and phosphorus solubilizing biofertilizer on pH, organic carbon, electrical conductivity (EC) and cation exchange capacity (CEC) of soil after harvest.

As evident from the result, the pH, EC and CEC of soils after harvest were not significantly influenced by the interaction between sulphur, boron and phosphorus solubilizing biofertilizer. The soil pH and EC was observed to decrease with increased levels of sulphur and boron fertilization along with phosphorus solubilizing biofertilizer but the decreased in soil pH and EC was found to be non significant. The highest pH and EC was observed in control plot, $S_0B_0P_0$ which recorded 5.49 and 5.48, 0.18 dS m^{-1} and 0.19 dS m^{-1} with pooled data of 5.48 and 0.19 dS m^{-1} while the lowest was observed with $S_2B_2P_1$ which recorded 5.32 and 5.30 with pooled data of 5.31, and EC of 0.16 dS m^{-1} during 2016 and 2017, respectively.

The organic carbon was not significantly influenced by the interaction between sulphur, boron and phosphorus solubilizing biofertilizer. The maximum organic carbon content in soil was obtained from treatment $S_2B_2P_1$ with 1.35% and 1.36% and pooled data of 1.36% whereas, $S_0B_0P_0$ (control) and $S_0B_0P_1$ obtained the lowest organic carbon content of 0.85% in 2016 and while $S_0B_0P_0$ recorded the lowest with 0.86% in 2017. In pooled data $S_0B_0P_0$ (control) and $S_0B_0P_1$ obtained the lowest organic carbon content of 0.86%.

The CEC was lowest in the control plot *i.e.*, $S_0B_0P_0$ with value of 14.25 cmol (p^+) kg^{-1} and 14.30 cmol (p^+) kg^{-1} and pooled data of 14.27 cmol (p^+) kg^{-1}

Table 4.6.1 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on pH, organic carbon, EC and CEC of soil after harvest

Treatments	**pH**			**Organic carbon (%)**			**EC (dS m^{-1})**			**CEC {cmol (p)kg^{-1}}**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
$S_0B_0P_0$	5.49	5.48	5.48	0.85	0.86	0.86	0.18	0.19	0.19	14.25	14.30	14.27
$S_0B_0P_1$	5.48	5.46	5.47	0.85	0.87	0.86	0.20	0.18	0.19	15.22	15.52	15.37
$S_0B_1P_0$	5.47	5.46	5.47	0.90	0.88	0.89	0.19	0.20	0.19	14.78	14.97	14.88
$S_0B_1P_1$	5.47	5.45	5.46	0.97	0.90	0.93	0.18	0.18	0.18	15.05	15.39	15.22
$S_0B_2P_0$	5.46	5.46	5.46	0.94	1.03	0.99	0.19	0.19	0.19	15.97	16.10	16.04
$S_0B_2P_1$	5.46	5.44	5.45	1.05	1.00	1.03	0.18	0.18	0.18	15.78	16.02	15.90
$S_1B_0P_0$	5.45	5.43	5.44	1.03	1.07	1.05	0.17	0.17	0.17	15.80	15.90	15.85
$S_1B_0P_1$	5.44	5.42	5.43	1.10	1.08	1.09	0.18	0.16	0.17	15.45	15.96	15.70
$S_1B_1P_0$	5.43	5.40	5.42	1.18	1.22	1.20	0.17	0.16	0.16	16.34	16.57	16.46
$S_1B_1P_1$	5.44	5.43	5.43	1.10	1.19	1.14	0.16	0.17	0.16	15.89	15.48	15.68
$S_1B_2P_0$	5.43	5.41	5.42	1.15	1.21	1.18	0.16	0.16	0.16	16.09	16.17	16.13
$S_1B_2P_1$	5.42	5.41	5.42	1.24	1.25	1.25	0.17	0.17	0.17	16.20	16.37	16.29
$S_2B_0P_0$	5.40	5.38	5.39	1.19	1.09	1.14	0.16	0.16	0.16	15.06	15.12	15.09
$S_2B_0P_1$	5.38	5.35	5.37	1.26	1.26	1.26	0.17	0.17	0.17	16.02	16.36	16.19
$S_2B_1P_0$	5.37	5.36	5.36	1.31	1.32	1.32	0.16	0.16	0.16	16.61	15.88	16.25
$S_2B_1P_1$	5.35	5.34	5.34	1.28	1.29	1.29	0.17	0.16	0.16	17.12	16.84	16.98
$S_2B_2P_0$	5.34	5.33	5.33	1.32	1.33	1.33	0.17	0.17	0.17	17.38	17.54	17.46
$S_2B_2P_1$	5.32	5.30	5.31	1.35	1.36	1.36	0.16	0.16	0.16	18.22	18.47	18.34
SEm±	**0.07**	**0.08**	**0.05**	***0.06***	***0.08***	***0.05***	***0.007***	***0.008***	***0.005***	***0.79***	***1.10***	***0.68***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***

while the highest CEC was observed with $S_2B_2P_1$ which recorded 18.22 cmol (p^+) kg^{-1} and 18.47 cmol (p^+) kg^{-1} with pooled data of 18.34 cmol (p^+) kg^{-1} during 2016 and 2017, respectively. There was no significant interaction effect on the CEC of soil.

4.6.2. Effect of sulphur, boron and phosphorus solubilizing biofertilizer on available N, P, K and S in soil after harvest

4.6.2.1. Effect of sulphur on available N, P, K and S in soil after harvest

Table 4.6.2 (a) presented the result on the effect of sulphur, boron and phosphorus solubilizing biofertilizer on available N, P, K and S in soil after harvest. As evident from the results, the available N and S were found to be significantly influenced by sulphur fertilization. Among the sulphur levels, S_2 (40 kg S ha^{-1}) recorded the maximum available N and S as 365.96 kg ha^{-1} and 368.90 kg ha^{-1}, 9.53 mg kg^{-1} and 9.63 mg kg^{-1} with pooled data as 367.43 kg ha^{-1} and 9.58 mg kg^{-1} during 2016 and 2017, respectively. The minimum available N and S in soil after harvest was recorded in S_0 as 324.14 kg ha^{-1} and 327.58 kg ha^{-1}, 7.13 mg kg^{-1} and 7.21 mg kg^{-1} and pooled data as 325.86 kg ha^{-1} and 7.17 mg kg^{-1} during 2016 and 2017, respectively.

The available N in soil after harvest increased significantly except in the control when compared with initial status (335.55 kg ha^{-1}). The build-up in available N in soil might be due to improved nutrient availability resulting in higher root activity and nitrogen fixation. The increased in the available S in soil might be due to the increased concentration of sulphur in soil through sulphur fertilization. Singh *et al.* (2014) observed substantial increased available N, P, K and S of soil with application of 20 kg S ha^{-1}. Kothari and Jethra (2002) also reported that increasing the levels of S application increases the available N, P and

Table 4.6.2 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on available N, P, K & S in soil after harvest

Treatments	N (kg ha^{-1})			P (kg ha^{-1})			K (kg ha^{-1})			S (mg kg^{-1})		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	324.14	327.58	325.86	9.52	9.85	9.69	183.30	180.59	181.95	7.13	7.21	7.17
S_1	347.06	349.87	348.46	10.32	10.35	10.33	183.37	183.23	183.30	8.41	8.42	8.42
S_2	365.96	368.90	367.43	10.45	10.62	10.53	185.16	184.99	185.08	9.53	9.63	9.58
SEm±	***0.37***	***0.38***	***0.27***	***0.20***	***0.18***	***0.13***	***0.73***	***2.40***	***1.26***	***0.09***	***0.09***	***0.06***
CD(P=0.05)	***1.46***	***1.50***	***0.87***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***0.34***	***0.35***	***0.20***
B_0	335.47	338.60	337.03	9.77	10.24	10.00	183.28	182.06	182.67	8.14	8.24	8.19
B_1	343.42	346.79	345.10	10.08	10.15	10.12	183.79	184.07	183.93	8.35	8.36	8.35
B_2	358.28	360.96	359.62	10.44	10.43	10.43	184.77	182.68	183.72	8.59	8.66	8.62
SEm±	***0.56***	***0.32***	***0.32***	***0.20***	***0.20***	***0.14***	***1.43***	***1.29***	***0.96***	***0.12***	***0.12***	***0.08***
CD(P=0.05)	***1.74***	***0.98***	***0.94***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
P_0	342.40	344.99	343.70	9.39	9.50	9.45	183.71	182.68	183.19	8.27	8.35	8.31
P_1	349.04	352.58	350.81	10.80	11.04	10.92	184.18	183.20	183.69	8.44	8.49	8.47
SEm±	***0.37***	***0.25***	***0.22***	***0.12***	***0.16***	***0.10***	***1.44***	***1.03***	***0.89***	***0.13***	***0.10***	***0.08***
CD(P=0.05)	***1.11***	***0.74***	***0.64***	***0.35***	***0.48***	***0.29***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***

S in soil. Meshram *et al.* (2017) opined that the highest available S in soil was obtained with application of 40 kg S ha^{-1}. Improved S availability in soil after harvest through sulphur application has been reported by Dhage *et al.* (2014), Najar *et al.* (2011) and Suman *et al.* (2018),

From the data depicted in Table 4.6.2 (a), it has become apparent that sulphur application did not have any significant effect on the available P and K in soil after harvest. The maximum available P and K was observed in S_2 as 10.45 kg ha^{-1} and 10.62 kg ha^{-1}, 185.16 kg ha^{-1} and 184.99 kg ha^{-1} during 2016 and 2017, respectively while pooled data had 10.53 kg ha^{-1} and 185.08 kg ha^{-1}. The minimum available P and K was recorded with S_0 as 9.52 kg ha^{-1} and 9.85 kg ha^{-1}, 183.30 kg ha^{-1} and 180.59 kg ha^{-1} during 2016 and 2017, respectively, while the pooled data had 9.69 kg ha^{-1} and 181.95 kg ha^{-1}.

4.6.2.2. Effect of boron on available N, P, K and S in soil after harvest

The data presented in Table 4.6.2 (a) revealed that boron fertilization had a significant influence on the available N in soil after harvest. The maximum available N and S were recorded from B_2 as 358.28 kg ha^{-1} and 360.96 kg ha^{-1}, during 2016 and 2017, respectively while the pooled data had 359.62 kg ha^{-1}. The minimum available N in soil after harvest were observed in B_0 as 335.47 kg ha^{-1} and 338.60 kg ha^{-1}, respectively during 2016 and 2017 while the pooled data had 337.03 kg ha^{-1}.

The increased available N in soil might be due to improved root activity and nitrogen fixation and also the role of boron in enhancing nitrogen fixation through nodule formation. Chatterjee and Bandyopadhyay (2017) also revealed that boron application significantly improved the available N, P and K in soil.

The maximum available P, K and S were recorded in B_2 as 10.44 kg ha^{-1} and 10.43 kg ha^{-1}, 184.77 kg ha^{-1} and 182.68 kg ha^{-1}, 8.59 mg kg^{-1} and 8.66 mg kg^{-1} and pooled data as 10.53 kg ha^{-1}, 183.72 kg ha^{-1} and 8.62 mg kg^{-1} during 2016 and 2017, respectively. The minimum available P, K and S were observed in B_0 as 9.77 kg ha^{-1} and 10.24 kg ha^{-1}, 183.28 kg ha^{-1} and 182.06 kg ha^{-1}, 8.14 mg kg^{-1} and 8.24 mg $kg^{-1}$and pooled data as 10.00 kg ha^{-1}, 182.67 kg ha^{-1} and 8.19 mg kg^{-1} during 2016 and 2017, respectively. The results revealed that boron fertilization did not have any significant influence on the available P, K and S in soil after harvest.

4.6.2.3. Effect of phosphorus solubilizing biofertilizer on available N, P, K and S in soil after harvest

As revealed from Table 4.6.2 (a), application of phosphorus solubilizing biofertilizer had a significant influence on the available N and P in soil after harvest. The results indicated that P_1 recorded higher available N and P as 349.04 kg ha^{-1} and 352.58 kg ha^{-1}, 10.80 kg ha^{-1} and 11.04 kg ha^{-1} with pooled data as 350.81 kg ha^{-1} and 10.92 kg ha^{-1} during 2016 and 2017, respectively as compared to P_0 which recorded 342.40 kg ha^{-1} and 344.99 kg ha^{-1}, 9.39 kg ha^{-1} and 9.50 kg ha^{-1} with pooled data as 343.70 kg ha^{-1} and 9.45 kg ha^{-1} during 2016 and 2017, respectively.

The increased in available nitrogen in soil could be due to improved nitrogen fixation through improved root activity and root nodulation. The application of phosphorus solubilizing biofertilizer might have increased the solubility of phosphate in the soil through production of organic acids leading to its increase availability in soil. The results are in agreement with the findings of Devi *et al.* (2013) and Kumar *et al.* (2017).

Higher available K and S in soil were observed when treatment P_1 was applied which recorded 184.14 kg ha^{-1} and 183.20 kg ha^{-1}, 8.44 mg kg^{-1} and 8.49 mg kg^{-1} with pooled data of 183.69 kg ha^{-1} and 8.47 mg kg^{-1} during 2016 and 2017, respectively. Treatment P_0 obtained slightly lower available P and S in soil with corresponding values of 183.71 kg ha^{-1} and 182.68 kg ha^{-1}, 8.28 mg kg^{-1} and 8.35 mg kg^{-1} with pooled data as 183.19 kg $ha^{-1}$and 8.31 mg kg^{-1} during 2016 and 2017, respectively. The available K and S in soil after harvest were not significantly influenced by phosphorus solubilizing biofertilizer.

4.6.2.4. Effect of sulphur and boron interaction on available N, P, K and S in soil after harvest

Table 4.6.2 (b) depicted the results on the interaction between the different treatments on the available N, P, K and S in soil after harvest. The interaction between sulphur and boron was observed to have a synergistic influence on the available N in soil after harvest. The highest available N was recorded in S_2B_2 as 381.77 kg ha^{-1} and 383 kg ha^{-1} during 2016 and 2017, respectively while the pooled data had 382.41 kg ha^{-1}. The lowest available N was recorded in the control (S_0B_0) as 311.17 kg ha^{-1} and 314.68 kg ha^{-1} in 2016 and 2017, respectively while the pooled data had 312.92 kg ha^{-1}. Treatment S_2B_2 was observed to be significantly higher than other treatment combinations.

The increased in the available nitrogen in soil might be due to the synergistic interaction between sulphur and boron which might have improved the nitrogen fixation capacity of the crop leaving behind higher residual N in the soil. Kader and Mona (2013) opined that combined application of (S + Zn + B) obtained the highest available N, P and K in soil. Chatterjee and Bandyopadhyay (2017) also observed significant effect of boron on the availability of macronutrients in soil.

Table 4.6.2 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on N, P, K & S content in soil after harvest

Treatments	**N (kg ha^{-1})**			**P (kg ha^{-1})**			**K (kg ha^{-1})**			**S (mg kg^{-1})**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0B_0	311.17	314.68	312.92	9.07	9.56	9.31	182.17	180.02	181.09	6.95	7.15	7.05
S_0B_1	322.17	326.73	324.45	9.54	9.81	9.67	184.06	181.90	182.98	7.24	7.21	7.22
S_0B_2	339.09	341.33	340.21	9.95	10.18	10.07	183.68	179.85	181.76	7.21	7.29	7.25
S_1B_0	342.74	345.14	343.94	10.20	10.52	10.36	183.94	184.45	184.19	8.22	8.27	8.25
S_1B_1	344.44	345.98	345.21	10.28	10.44	10.36	183.99	184.01	184.00	8.39	8.44	8.42
S_1B_2	353.99	358.48	356.23	10.48	10.09	10.28	182.17	181.23	181.70	8.64	8.53	8.59
S_2B_0	352.49	355.99	354.24	10.04	10.63	10.34	183.73	181.73	182.73	9.24	9.31	9.28
S_2B_1	363.64	367.66	365.65	10.42	10.21	10.32	183.31	186.30	184.80	9.41	9.42	9.42
S_2B_2	381.77	383.06	382.41	10.87	11.02	10.94	188.45	186.95	187.70	9.93	10.15	10.04
SEm±	***0.98***	***0.55***	***0.56***	***0.35***	***0.35***	***0.25***	***2.47***	***2.23***	***1.66***	***0.20***	***0.21***	***0.14***
CD(P=0.05)	***3.01***	***1.70***	***1.63***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
S_0P_0	321.82	323.98	322.90	8.80	9.04	8.92	180.29	178.41	179.35	7.08	7.16	7.12
S_0P_1	326.47	331.18	328.82	10.24	10.67	10.45	186.31	182.76	184.54	7.18	7.27	7.22
S_1P_0	343.51	345.92	344.72	9.58	9.58	9.58	184.91	184.58	184.74	8.39	8.38	8.38
S_1P_1	350.60	353.82	352.21	11.06	11.12	11.09	181.83	181.88	181.85	8.44	8.45	8.45
S_2P_0	361.88	365.08	363.48	9.79	9.90	9.84	185.92	185.03	185.48	9.35	9.51	9.43
S_2P_1	370.05	372.73	371.39	11.10	11.34	11.22	184.40	184.95	184.68	9.70	9.75	9.73
SEm±	***0.65***	***0.43***	***0.39***	***0.20***	***0.28***	***0.17***	***2.50***	***1.78***	***1.53***	***0.23***	***0.17***	***0.14***
CD(P=0.05)	***1.92***	***1.27***	***1.11***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
B_0P_0	332.21	334.39	333.30	9.15	9.63	9.39	182.45	181.91	182.18	8.05	8.19	8.12
B_0P_1	338.72	342.81	340.77	10.39	10.84	10.62	184.11	182.22	183.17	8.22	8.30	8.26
B_1P_0	339.63	342.90	341.27	9.19	9.60	9.40	184.02	183.57	183.80	8.29	8.29	8.29
B_1P_1	347.21	350.67	348.94	10.97	10.71	10.84	183.55	184.57	184.06	8.40	8.42	8.41
B_2P_0	355.38	357.67	356.52	9.83	9.28	9.55	184.66	182.55	183.60	8.48	8.56	8.52
B_2P_1	361.19	364.24	362.71	11.04	11.58	11.31	184.88	182.81	183.84	8.70	8.75	8.73
SEm±	***0.65***	***0.43***	***0.39***	***0.20***	***0.28***	***0.17***	***2.50***	***1.78***	***1.53***	***0.23***	***0.17***	***0.14***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***

From the results presented in Table 4.6.2 (b), it has been revealed that the interaction between sulphur and boron did not have any significant influence on the available P, K and S in soil after harvest. The highest available P, K and S were recorded in S_2B_2 as 10.87 kg ha^{-1} and 11.02 kg ha^{-1}, 188.45 kg ha^{-1} and 186.95 kg ha^{-1}, 9.93 mg kg^{-1} and 10.15 mg kg^{-1} during 2016 and 2017, respectively, while the pooled data had 10.94 kg ha^{-1} and 184.68 kg ha^{-1} and 10.04 mg kg^{-1}, respectively. The lowest available P, K and S were recorded with S_0B_0 as 9.07 kg ha^{-1} and 9.56 kg ha^{-1}, 182.17 kg ha^{-1} and 180.02 kg ha^{-1} and 6.95 mg kg^{-1} and 7.15 mg kg^{-1} while the pooled data had 9.31 kg ha^{-1} and 181.09 kg ha^{-1} and 7.05 mg kg^{-1} during 2016 and 2017, respectively.

4.6.2.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on available N, P, K and S in soil after harvest

From the data depicted in Table 4.6.2 (b), it has been observed that available N was significantly influenced by the interaction between sulphur and phosphorus solubilizing biofertilizer. The maximum available N was recorded with S_2P_1 as 370.05 kg ha^{-1} and 372.73 kg ha^{-1} during 2016 and 2017, respectively while the pooled data had 371.39 kg ha^{-1} and 9.73 mg kg^{-1}. The minimum available N was recorded with S_0P_0 as 321.82 kg ha^{-1} and 323.98 kg ha^{-1} during 2016 and 2017, respectively while the pooled data had 322.90 kg ha^{-1}. It was observed that application of phosphorus solubilizing biofertilizer at all levels of sulphur further increases the available S in soil than application of sulphur alone.

The increased in available nitrogen in soil could be due to improved nitrogen fixation through improved root activity and root nodulation. Singh *et al.* (2014) revealed that P and S have significant interaction effect on available N content in soil. Dhage *et al.* (2008) also observed significant interaction effect between chemical fertilizers and biofertilizers (PSB) on nitrogen content in soil at harvest.

As evident from the results, the interaction between sulphur and phosphorus solubilizing biofertilizer did not any significant influence on the available P, K and S in soil after harvest. It was observed that S_2P_1 recorded the highest available P, K and S as 11.10 kg ha^{-1} and 11.34 kg ha^{-1}, 184.40 kg ha^{-1} and 184.95 kg ha^{-1} , 9.70 mg kg^{-1} and 9.75 mg kg^{-1} during 2016 and 2017, respectively, while the pooled data had 11.22 kg ha^{-1} and 184.68 kg ha^{-1}. It was revealed that the lowest available P, K and S recorded in S_0P_0 as 8.80 kg ha^{-1} and 9.04 kg ha^{-1}, 180.29 kg ha^{-1} and 178.41 kg ha^{-1}, 7.08 mg kg^{-1} and 7.16 mg kg^{-1} during 2016 and 2017, respectively, while the pooled data had 8.92 kg ha^{-1}, 179.35 kg ha^{-1} and 7.12 mg kg^{-1}.

4.6.2.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on available N, P, K and S in soil after harvest

From the data depicted on Table 4.6.2 (b), the interaction between boron and phosphorus solubilizing biofertilizer did not have any significant effect on the available N, P, K and S in soil after harvest. The maximum available N, P, K and S in soil after harvest were recorded in B_2P_1 as 361.19 kg ha^{-1} and 364.24 kg ha^{-1}, 11.04 kg ha^{-1} and 11.58 kg ha^{-1}, 184.88 kg ha^{-1} and 182.81 kg ha^{-1}, 8.70 mg kg^{-1} and 8.75 mg kg^{-1} during 2016 and 2017, respectively while the pooled data had 362.71 kg ha^{-1}, 11.31 kg ha^{-1}, 183.84 kg ha^{-1} and 8.73 mg kg^{-1}. The minimum available N, P, K and S in soil after harvest were recorded in B_0P_0 as 332.21 kg ha^{-1} and 334.39 kg ha^{-1}, 9.15 kg ha^{-1} and 9.63 kg ha^{-1}, 182.45 kg ha^{-1} and 181.91 kg ha^{-1}, 8.06 mg kg^{-1} and 8.19 mg kg^{-1} during 2016 and 2017, respectively while the pooled data had 333.30 kg ha^{-1}, 9.39 kg ha^{-1}, 182.18 kg ha^{-1} and 8.12 mg kg^{-1}.

4.6.2.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on available N, P, K and S in soil after harvest

The interaction effect of sulphur, boron and phosphorus solubilizing biofertilizer on available N, P, K and S in soil after harvest has been presented in Table 4.6.2 (c). The results indicated that the available N in soil after harvest was significantly influenced by the interaction between sulphur, boron and phosphorus solubilizing biofertilizer. The maximum available N was recorded in plots receiving treatment $S_2B_2P_1$ as 386.80 kg ha^{-1} and 388.48 kg ha^{-1} during 2016 and 2017, respectively while the pooled data had 387.64 kg ha^{-1}. The minimum available N was recorded in $S_0B_0P_0$ (control) as 309.98 kg ha^{-1} and 310.32kg ha^{-1} during 2016 and 2017, respectively while the pooled data had 310.15 kg ha^{-1}.

Kothari and Jethra (2002) also reported that increasing the levels of S application increases the available N in soil. Kader and Mona (2013) opined that combined application of (S + B) obtained higher available N in soil over control. Devi *et al.* (2013) and Kumar *et al.* (2017) also observed significant increased in available N in soil with application of PSB.

As evident from the results, the interaction between sulphur, boron and phosphorus solubilizing biofertilizer did not have any significant influence on the available P, K and S in soil after harvest. The maximum available P, K and S was recorded in $S_2B_2P_1$ as 11.48 kg ha^{-1} and 12.06 kg ha^{-1}, 188.51 kg ha^{-1} and 187.84 kg ha^{-1}, 10.15 mg kg^{-1} and 10.29 mg kg^{-1} during 2016 and 2017, respectively while the pooled data had 11.77 kg ha^{-1}, 188.17 kg ha^{-1} and 10.22 mg kg^{-1}, respectively. The minimum available P, K and S were in the control treatment, $S_0B_0P_0$ as 8.51 kg ha^{-1} and 8.89 kg ha^{-1}, 177.40 kg ha^{-1} and 176.42 kg ha^{-1}, 6.84 mg kg^{-1} and 7.07 mg kg^{-1} during 2016 and 2017, respectively, while the pooled data had 8.70 kg ha^{-1} and 176.91 kg ha^{-1} and 6.95 mg kg^{-1}, respectively.

Table 4.6.2 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on N, P, K & S content in soil after harvest

Treatments	N (kg ha^{-1})			P (kg ha^{-1})			K (kg ha^{-1})			S (mg kg^{-1})		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
$S_0B_0P_0$	309.98	310.32	310.15	8.51	8.89	8.70	177.40	176.42	176.91	6.84	7.07	6.95
$S_0B_0P_1$	312.36	319.03	315.70	9.63	10.23	9.93	186.94	183.61	185.28	7.05	7.22	7.14
$S_0B_1P_0$	318.71	322.19	320.45	8.58	9.25	8.91	182.52	180.85	181.68	7.16	7.15	7.16
$S_0B_1P_1$	325.63	331.27	328.45	10.49	10.38	10.44	185.60	182.96	184.28	7.31	7.26	7.29
$S_0B_2P_0$	336.77	339.43	338.10	9.32	8.97	9.14	180.96	177.96	179.46	7.24	7.25	7.25
$S_0B_2P_1$	341.41	343.24	342.32	10.59	11.40	10.99	186.39	181.73	184.06	7.17	7.32	7.25
$S_1B_0P_0$	337.82	340.02	338.92	9.59	9.90	9.75	184.86	187.21	186.04	8.13	8.23	8.18
$S_1B_0P_1$	347.66	350.26	348.96	10.81	11.14	10.98	183.01	181.68	182.34	8.30	8.32	8.31
$S_1B_1P_0$	340.09	341.77	340.93	9.24	9.93	9.59	185.25	182.91	184.08	8.53	8.48	8.51
$S_1B_1P_1$	348.79	350.18	349.49	11.32	10.95	11.13	182.74	185.11	183.93	8.25	8.40	8.33
$S_1B_2P_0$	352.63	355.95	354.29	9.90	8.90	9.40	184.61	183.62	184.12	8.50	8.42	8.46
$S_1B_2P_1$	355.34	361.01	358.18	11.06	11.27	11.16	179.73	178.85	179.29	8.78	8.64	8.71
$S_2B_0P_0$	348.83	352.84	350.84	9.36	10.10	9.73	185.08	182.08	183.58	9.17	9.26	9.22
$S_2B_0P_1$	356.14	359.14	357.64	10.72	11.16	10.94	182.38	181.38	181.88	9.31	9.36	9.34
$S_2B_1P_0$	360.08	364.75	362.42	9.75	9.63	9.69	184.29	186.96	185.62	9.19	9.24	9.22
$S_2B_1P_1$	367.20	370.56	368.88	11.10	10.80	10.95	182.32	185.64	183.98	9.63	9.61	9.62
$S_2B_2P_0$	376.73	377.64	377.18	10.27	9.97	10.12	188.39	186.06	187.23	9.70	10.02	9.86
$S_2B_2P_1$	386.80	388.48	387.64	11.48	12.06	11.77	188.51	187.84	188.17	10.15	10.29	10.22
SEm±	***1.12***	***0.74***	***0.67***	***0.35***	***0.49***	***0.30***	***4.33***	***3.08***	***2.66***	***0.40***	***0.29***	***0.25***
CD(P=0.05)	***3.33***	***2.21***	***1.93***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***

4.6.3. Effect of sulphur, boron and phosphorus solubilizing biofertilizer on exchangeable Ca & Mg and B in soil after harvest

4.6.3.1. Effect of sulphur on exchangeable Ca & Mg and B in soil after harvest

The effect of boron and phosphorus solubilizing biofertilizer on exchangeable Ca, exchangeable Mg and B in soil after harvest were presented in Table 4.6.3 (a). It has been revealed from the results that application of sulphur did not have any significant influence on the exchangeable Ca, exchangeable Mg and B in soil after harvest. The maximum exchangeable Ca was recorded in S_0 with 4.73 cmol (p^+) kg^{-1} and 4.80 cmol (p^+) kg^{-1} with pooled a value of 4.76 cmol (p^+) kg^{-1} while S_2 recorded the lowest of 3.36 cmol (p^+) kg^{-1} and 3.31 cmol (p^+) kg^{-1} with pooled data of 3.34 cmol (p^+) kg^{-1} during 2016 and 2017, respectively. The exchangeable Mg of 0.55 cmol (p^+) kg^{-1} and 0.54 cmol (p^+) kg^{-1} with pooled data as 0.54 cmol (p^+) kg^{-1} was highest with S_2 while the lowest was recorded in S_0 with 0.45 cmol (p^+) kg^{-1} and 0.46 cmol (p^+) kg^{-1} and a pooled value of 0.54 cmol (p^+) kg^{-1} during 2016 and 2017, respectively. The available B in soil was highest in S_1 as 0.58 mg kg^{-1} and 0.59 mg kg^{-1} with pooled data of 0.58 mg kg^{-1} while S_0 recorded the lowest with 0.54 mg kg^{-1} and 0.57 mg kg^{-1} with pooled data as 0.55 mg kg^{-1} during 2016 and 2017, respectively.

4.6.3.2. Effect of boron on exchangeable Ca & Mg and B in soil after harvest

The results depicted in Table 4.6.3 (a) revealed that boron fertilization did not have any significant influence on the exchangeable Ca and Mg in soil after harvest. The maximum exchangeable Ca was observed with B_0 (control) as 4.06 cmol (p^+) kg^{-1} and 4.08 cmol (p^+) kg^{-1} whereas B_2 recorded the lowest with 3.80

Table 4.6.3 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on exchangeable Ca & Mg and B content in soil after harvest

Treatments	**Ca {cmol (p)kg^{-1}}**			**Mg {cmol (p)kg^{-1}}**			**B (mg kg^{-1})**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	4.73	4.80	4.76	0.45	0.46	0.45	0.54	0.57	0.55
S_1	3.65	3.67	3.66	0.50	0.49	0.50	0.58	0.59	0.58
S_2	3.36	3.31	3.34	0.55	0.54	0.54	0.56	0.58	0.57
SEm±	***0.28***	***0.30***	***0.20***	***0.019***	***0.020***	***0.014***	***0.009***	***0.009***	***0.006***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
B_0	4.06	4.08	4.07	0.49	0.48	0.49	0.43	0.45	0.44
B_1	3.89	3.94	3.91	0.49	0.49	0.49	0.58	0.58	0.58
B_2	3.80	3.76	3.78	0.52	0.51	0.52	0.67	0.70	0.68
SEm±	***0.13***	***0.17***	***0.11***	***0.010***	***0.009***	***0.007***	***0.006***	***0.004***	***0.004***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***0.017***	***0.014***	***0.010***
P_0	3.99	4.01	4.00	0.49	0.50	0.49	0.55	0.57	0.56
P_1	3.83	3.84	3.84	0.51	0.50	0.50	0.57	0.59	0.58
SEm±	***0.12***	***0.18***	***0.11***	***0.010***	***0.008***	***0.006***	***0.007***	***0.006***	***0.004***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***

cmol (p$^+$) kg^{-1} and 3.76 cmol (p$^+$) kg^{-1} during 2016 and 2017, respectively, while the pooled data had 4.07cmol (p$^+$) kg^{-1} and 3.78 cmol (p$^+$) kg^{-1}. The exchangeable Mg was maximum in B_2 with 0.51 cmol (p$^+$) kg^{-1} and 0.50 cmol (p$^+$) kg^{-1} whereas the minimum was recorded with B_0 as 0.49 cmol (p$^+$) kg^{-1} and 0.48 cmol (p$^+$) kg^{-1} during 2016 and 2017, respectively, while the pooled data had 0.52 cmol (p$^+$) kg^{-1} and 0.49 cmol (p$^+$) kg^{-1}. The available B in soil after harvest was observed to be significantly influenced by boron fertilization. The highest available B in soil after harvest was highest in B_2 (2 kg B ha^{-1}) with 0.67 mg kg^{-1} and 0.70 mg kg^{-1} with pooled data as 0.68 mg kg^{-1} while the lowest was recorded in B_0 as 0.43 mg kg^{-1} and 0.45 mg kg^{-1} with pooled data as 0.44 mg kg^{-1} during 2016 and 2017, respectively.

The increased availability of B might be due to application of increased levels of boron. Meshram *et al.* (2017) also reported that increasing the levels of boron fertilization increases the available boron in soil.

4.6.3.3. Effect of phosphorus solubilizing biofertilizer on exchangeable Ca & Mg and B in soil after harvest

From the data presented in Table 4.6.3 (a), it has been revealed that application of phosphorus solubilizing biofertilizer did not have any significant influence on the exchangeable Ca, exchangeable Mg and B in soil after harvest and there was no significant variations observed between P_0 and P_1. The exchangeable Ca observed with P_0 recorded 3.99 cmol (p$^+$) kg^{-1} and 4.01 cmol (p$^+$) kg^{-1} with pooled data as 4.00 cmol (p$^+$) kg^{-1} while P_1 recorded slightly lower with 3.83 cmol (p$^+$) kg^{-1} and 3.84 cmol (p$^+$) kg^{-1} with pooled data as 3.84 cmol (p$^+$) kg^{-1} during 2016 and 2017, respectively. The exchangeable Mg recorded slightly with P_1 as 0.51 cmol (p$^+$) kg^{-1} and 0.50 cmol (p$^+$) kg^{-1} with pooled data as 0.50 cmol (p$^+$) kg^{-1} while P_0 recorded 0.49 cmol (p$^+$) kg^{-1} and 0.50 cmol (p$^+$) kg^{-1} with pooled data as 0.49 cmol (p^+) kg^{-1} during 2016 and 2017, respectively. The available B in soil recorded with P_1 as 0.57 mg kg^{-1} and 0.59 mg kg^{-1} with pooled data as 0.58 mg kg^{-1} while P_0 which recorded 0.55 mg kg^{-1} and 0.57 mg kg^{-1} with pooled data as 0.56 mg kg^{-1} during 2016 and 2017, respectively.

4.6.3.4. Effect of sulphur and boron interaction on exchangeable Ca & Mg and B in soil after harvest

Table 4.6.3 (b) presented the interaction between sulphut and boron, sulphur and phosphorus solubilizing biofertilizer, and boron and phosphorus solubilizing biofertilizer on exchangeable Ca, exchangeable Mg and B in soil after harvest. The results revealed that the interaction between sulphur and boron did not have any significant influence on the exchangeable Ca and Mg and available B in soil after harvest. The maximum exchangeable Ca was observed in S_0B_0 as 4.90 cmol (p^+) kg^{-1} and 4.96 cmol (p^+) kg^{-1} with pooled data as 4.93 cmol (p^+) kg^{-1} while S_2B_2 recorded the lowest with 3.36 cmol (p^+) kg^{-1} and 3.18 cmol (p^+) kg^{-1} with pooled data as 3.27 cmol (p^+) kg^{-1} during 2016 and 2017, respectively. The exchangeable Mg was highest in S_2B_2 which recorded 0.57 cmol (p^+) kg^{-1} and 0.55 cmol (p^+) kg^{-1} with pooled data as 0.56 cmol (p^+) kg^{-1} during 2016 and 2017, respectively, while S_0B_0 recorded the lowest with 0.44 cmol (p^+) kg^{-1} in both 2016 and 2017. The available B in soil after harvest was highest in treatment S_2B_2 as 0.69 mg kg^{-1} and 0.71 mg kg^{-1} with pooled data as 0.70 mg kg^{-1} while the lowest was observed with S_0B_0 as 0.41 mg kg^{-1} and 0.44 mg kg^{-1} with a pooled data of 0.42 mg kg^{-1} during 2016 and 2017, respectively.

Table 4.6.3 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on exchangeable Ca & Mg and B content in soil after harvest

Treatments	Ca {cmol (p)kg^{-1}}			Mg {cmol (p)kg^{-1}}			B (mg kg^{-1})		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0B_0	4.90	4.96	4.93	0.44	0.44	0.44	0.41	0.44	0.42
S_0B_1	4.62	4.70	4.66	0.46	0.46	0.46	0.57	0.58	0.57
S_0B_2	4.68	4.74	4.71	0.46	0.47	0.46	0.64	0.68	0.66
S_1B_0	3.93	3.97	3.95	0.47	0.48	0.47	0.46	0.47	0.47
S_1B_1	3.65	3.67	3.66	0.49	0.49	0.49	0.61	0.58	0.59
S_1B_2	3.37	3.37	3.37	0.53	0.52	0.52	0.68	0.71	0.69
S_2B_0	3.35	3.31	3.33	0.55	0.53	0.54	0.43	0.46	0.44
S_2B_1	3.38	3.44	3.41	0.53	0.53	0.53	0.56	0.58	0.57
S_2B_2	3.36	3.18	3.27	0.57	0.55	0.56	0.69	0.71	0.70
SEm±	***0.23***	***0.29***	***0.18***	***0.017***	***0.015***	***0.011***	***0.010***	***0.008***	***0.006***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
S_0P_0	4.91	5.04	4.98	0.45	0.46	0.45	0.53	0.55	0.54
S_0P_1	4.56	4.55	4.55	0.45	0.45	0.45	0.55	0.58	0.57
S_1P_0	3.68	3.72	3.70	0.49	0.49	0.49	0.58	0.58	0.58
S_1P_1	3.62	3.62	3.62	0.51	0.49	0.50	0.59	0.59	0.59
S_2P_0	3.40	3.28	3.34	0.54	0.54	0.54	0.55	0.57	0.56
S_2P_1	3.33	3.34	3.34	0.56	0.54	0.55	0.57	0.59	0.58
SEm±	***0.20***	***0.31***	***0.18***	***0.016***	***0.014***	***0.011***	***0.011***	***0.010***	***0.008***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***
B_0P_0	4.04	4.20	4.12	0.48	0.48	0.48	0.43	0.45	0.44
B_0P_1	4.07	3.96	4.01	0.49	0.49	0.49	0.44	0.46	0.45
B_1P_0	4.02	4.04	4.03	0.48	0.49	0.49	0.58	0.58	0.58
B_1P_1	3.75	3.83	3.79	0.50	0.49	0.50	0.57	0.58	0.58
B_2P_0	3.92	3.80	3.86	0.51	0.51	0.51	0.64	0.67	0.66
B_2P_1	3.68	3.72	3.70	0.52	0.51	0.52	0.70	0.73	0.71
SEm±	***0.20***	***0.31***	***0.18***	***0.016***	***0.014***	***0.011***	***0.011***	***0.010***	***0.008***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***0.033***	***0.030***	***0.022***

4.6.3.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on exchangeable Ca & Mg and B in soil after harvest

As shown in Table 4.6.3 (b), it has become apparent that the interaction between sulphur and phosphorus solubilizing biofertilizer did not have any significant influence on the exchangeable Ca, Mg and available B in soil after harvest. The data revealed that the highest exchangeable Ca was observed with S_0P_0 as 4.91 cmol (p^+) kg^{-1} and 5.04 cmol (p^+) kg^{-1} with a pooled data of 4.98 cmol (p^+) kg^{-1} whereas S_2P_1 recorded the lowest with 3.33 cmol (p^+) kg^{-1} and 3.34 cmol (p^+) kg^{-1} with a pooled data of 3.34 cmol (p^+) kg^{-1} during 2016 and 2017, respectively. The exchangeable Mg on the other hand, was highest with S_2P_1 which recorded 0.56 cmol (p^+) kg^{-1} and 0.54 cmol (p^+) kg^{-1} with a pooled data of 0.55 cmol (p^+) kg^{-1} while S_0P_0 recorded the lowest with 0.45 cmol (p^+) kg^{-1} and 0.46 cmol (p^+) kg^{-1} and a pooled 0.45 cmol (p^+) kg^{-1} during 2016 and 2017, respectively. The highest available B was recorded with S_1P_1 as 0.59 cmol (p^+) kg^{-1} in 2016, while in 2017, S_1P_1 and S_2P_1 recorded the highest where both recorded 0.59 cmol (p^+) kg^{-1}. In the pooled data, S_1P_1 recorded the highest available B in soil with a value of 0.590.59 cmol (p^+) kg^{-1}. The lowest available B in soil after harvest was recorded with S_0P_0 as 0.53 cmol (p^+) kg^{-1} and 0.55 cmol (p^+) kg^{-1} and pooled data had 0.540.59 cmol (p^+) kg^{-1} during 2016 and 2017, respectively.

4.6.3.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on exchangeable Ca & Mg and B in soil after harvest

From the data presented in Table 4.6.3 (b), it has been revealed that the effect of interaction between boron and phosphorus solubilizing biofertilizer on exchangeable Ca and exchangeable Mg are not significant. The maximum exchangeable Ca was observed with B_0P_1 which recorded 4.07 cmol (p^+) kg^{-1} in 2016 while B_0P_0 recorded the highest with 4.20 cmol (p^+) kg^{-1} in 2017 and in the pooled data, B_0P_0 recorded the maximum exchangeable Ca with 4.12 cmol (p^+) kg^{-1}. The lowest exchangeable Ca was observed with B_2P_1 which recorded 3.68 cmol (p^+) kg^{-1} and 3.72 cmol (p^+) kg^{-1} with pooled data as 3.70 cmol (p^+) kg^{-1} during 2016 and 2017, respectively. The exchangeable Mg was maximum in B_2P_1 which recorded 0.52 cmol (p^+) kg^{-1} in 2016 and B_2P_1 and B_2P_0 recorded the maximum both having 0.51 cmol (p^+) kg^{-1} in 2017, while in the pooled data B_2P_1 recorded the highest exchangeable Mg of 0.52 cmol (p^+) kg^{-1}. The lowest exchangeable Mg was observed with B_0P_0 which recorded 0.48 cmol (p^+) kg^{-1} both in 2016 and 2017. The available B in soil after harvest was observed to be significantly influenced by the interaction between boron and phosphorus solubilizing biofertilizer. The highest available B was observed where B_2P_1 was applied which recorded 0.70 mg kg^{-1} and 0.7 mg kg^{-1} with a pooled data of 0.71 mg kg^{-1} whereas the lowest was observed with B_0P_0 which recorded 0.43 mg kg^{-1} and 0.45 mg kg^{-1} with pooled data of 0.44 mg kg^{-1} during 2016 and 2017, respectively. From the pooled data, it was apparent that B_1P_0 was at par with B_1P_1.

The improved availability of boron in soil might be due to its increased concentration in the soil through boron application. This is in agreement with Meshram *et al.* (2017) and Yadav *et al.* (2016) also reported that increasing the levels of boron fertilization increases the available boron in soil.

4.6.3.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on exchangeable Ca & Mg and B in soil after harvest

The interaction effect between sulphur, boron and phosphorus solubilizing biofertilizer on exchangeable Ca, exchangeable Mg and B in soil after harvest has been shown in Table 4.6.3 (c). It has been observed that the exchangeable Ca and Mg were not significantly influenced by the interaction between sulphur, boron and phosphorus solubilizing biofertilizer. The highest exchangeable Ca was

Table 4.6.3 (c) Interaction effect of sulfur, boron and phosphorus solubilizing biofertilizer on exchangeable Ca & Mg and B content in soil after harvest

Treatments	Ca {cmol (p)kg^{-1}}			Mg {cmol (p)kg^{-1}}			B (mg kg^{-1})		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
$S_0B_0P_0$	4.75	5.08	4.92	0.43	0.44	0.44	0.40	0.42	0.41
$S_0B_0P_1$	5.04	4.83	4.94	0.44	0.45	0.45	0.42	0.45	0.43
$S_0B_1P_0$	4.97	5.12	5.04	0.46	0.46	0.46	0.57	0.58	0.57
$S_0B_1P_1$	4.27	4.29	4.28	0.45	0.46	0.46	0.56	0.59	0.58
$S_0B_2P_0$	5.00	4.93	4.97	0.46	0.47	0.47	0.61	0.65	0.63
$S_0B_2P_1$	4.35	4.54	4.45	0.46	0.46	0.46	0.67	0.72	0.69
$S_1B_0P_0$	4.00	4.20	4.10	0.47	0.48	0.47	0.45	0.47	0.46
$S_1B_0P_1$	3.85	3.73	3.79	0.48	0.47	0.48	0.46	0.47	0.47
$S_1B_1P_0$	3.69	3.64	3.66	0.47	0.48	0.47	0.62	0.58	0.60
$S_1B_1P_1$	3.62	3.70	3.66	0.51	0.50	0.51	0.60	0.57	0.59
$S_1B_2P_0$	3.34	3.31	3.33	0.52	0.53	0.52	0.66	0.69	0.67
$S_1B_2P_1$	3.40	3.42	3.41	0.53	0.51	0.52	0.70	0.73	0.72
$S_2B_0P_0$	3.38	3.30	3.34	0.54	0.53	0.53	0.44	0.45	0.45
$S_2B_0P_1$	3.31	3.32	3.32	0.56	0.54	0.55	0.42	0.46	0.44
$S_2B_1P_0$	3.39	3.38	3.39	0.52	0.54	0.53	0.56	0.58	0.57
$S_2B_1P_1$	3.37	3.50	3.43	0.53	0.52	0.53	0.56	0.57	0.57
$S_2B_2P_0$	3.42	3.15	3.28	0.56	0.54	0.55	0.65	0.68	0.66
$S_2B_2P_1$	3.30	3.21	3.26	0.58	0.56	0.57	0.73	0.74	0.74
SEm±	***0.35***	***0.53***	***0.32***	***0.029***	***0.025***	***0.019***	***0.020***	***0.018***	***0.013***
CD(P=0.05)	***NS***	***NS***	***NS***	***NS***	***NS***	***NS***	***0.058***	***0.052***	***0.038***

recorded with $S_0B_0P_1$ in 2016 as 5.04 cmol (p^+) kg^{-1} while in 2017, $S_0B_1P_0$ recorded the highest with 5.12 cmol (p^+) kg^{-1} and in the pooled data $S_0B_1P_0$ was highest with 5.04 cmol (p^+) kg^{-1}. The lowest exchangeable Ca was observed in $S_2B_2P_1$ as 3.30 cmol (p^+) kg^{-1} and 3.21 cmol (p^+) kg^{-1} with pooled data as 3.26 cmol (p^+) kg^{-1} during 2016 and 2017, respectively. The highest exchangeable Mg was observed in $S_2B_2P_1$ as 0.58 cmol (p^+) kg^{-1} and 0.56 cmol (p^+) kg^{-1} and pooled data of 0.57 cmol (p^+) kg^{-1} whereas, the lowest was recorded in $S_0B_0P_0$ as 0.43 cmol (p^+) kg^{-1} and 0.44 cmol (p^+) kg^{-1} with a pooled data of 0.44 cmol (p^+) kg^{-1} during 2016 and 2017, respectively.

As evident from the results, the interaction between sulphur, boron and phosphorus solubilizing biofertilizer have a significant influence on the available B in soil after harvest. The maximum available B in soil was recorded in $S_2B_2P_1$ as 0.73 mg kg^{-1} and 0.74 mg kg^{-1} with pooled data as 0.74 mg kg^{-1} while the lowest was recorded in $S_0B_0P_0$ as 0.40 mg kg^{-1} and 0.42 mg kg^{-1} with pooled data as 0.41 mg kg^{-1} during 2016 and 2017, respectively. The pooled data revealed that $S_1B_2P_1$ was at par with $S_2B_2P_1$, while $S_0B_2P_1$ was at par with $S_1B_2P_0$, and also $S_0B_1P_0$, $S_0B_1P_1$, $S_2B_1P_0$ and $S_2B_1P_1$ were at par with each other. The improved availability of boron in soil might be due to its increased concentration in the soil through boron application (Meshram *et al.,* 2017). Kader and Mona (2013) observed that sulphur application increases the boron availability in soil. Dhage *et al*. (2008) revealed that 100 % RDF with dual inoculation (*Rhizobium* + PSB) improved soil fertility.

4.6.4. Effect of sulphur, boron and phosphorus solubilizing biofertilizer on soil microbial biomass carbon and soil respiration in soil after harvest

4.6.4.1. Effect of sulphur on soil microbial biomass carbon and soil respiration after harvest

The results on soil microbial biomass carbon and soil respiration after harvest have been presented in Table 4.6.4 (a) and Fig. 10. The results revealed that sulphur application had a significant influence on the soil microbial biomass carbon and soil respiration after harvest. The highest soil microbial biomass carbon and soil respiration after harvest were observed in S_2 as 214.70 μg g^{-1} and 219.53 μg g^{-1}, 4.86 μg C g^{-1} hr^{-1} and 5.07 μg C g^{-1} hr^{-1} during 2016 and 2017, respectively, while the pooled data had 217.11 μg g^{-1} and 6.19 μg C g^{-1} hr^{-1}. The lowest soil microbial biomass carbon and soil respiration after harvest were recorded in S_0 as 172.11 μg g^{-1} and 175.11 μg g^{-1}, 4.48 μg C g^{-1} hr^{-1} and 5.07 μg C g^{-1} hr^{-1} during 2016 and 2017, respectively while the pooled data had 173.97 μg g^{-1} and 4.97 μg C g^{-1} hr^{-1}.

Similar findings on soil microbial biomass carbon had been reported by Verma *et al*. (2018) and Singh *et al*., (2015). The improved soil microbial biomass carbon might be due to improved plant nutrition which improves the soil organic matter content through higher root biomass.

4.6.4.2. Effect of boron on soil microbial biomass carbon and soil respiration after harvest

From the data depicted in Table 4.6.4 (a) and Fig. 10, it has been revealed that boron fertilization up to 2 kg B ha^{-1} significantly influence the soil microbial biomass carbon and soil respiration after harvest. The maximum soil microbial biomass carbon and soil respiration after harvest were observed with B_2 which recorded 197.77 μg g^{-1} and 203.90 μg g^{-1}, 5.76 μg C g^{-1} hr^{-1} and 5.91 μg C g^{-1} hr^{-1} during

Table 4.6.4 (a) Effect of sulfur, boron and phosphorus solubilizing biofertilizer on soil microbial biomass carbon and soil respiration

Treatments	**Soil microbial biomass carbon (μg/g)**			**Soil Respiration (μg C g^{-1} hr^{-1})**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0	172.11	175.82	173.97	4.86	5.07	4.97
S_1	190.40	193.22	191.81	5.42	5.59	5.51
S_2	214.70	219.53	217.11	6.11	6.27	6.19
SEm±	***0.37***	***0.49***	***0.31***	***0.007***	***0.012***	***0.007***
CD(P=0.05)	***1.45***	***1.91***	***1.00***	***0.027***	***0.046***	***0.022***
B_0	184.55	185.99	185.27	5.32	5.40	5.36
B_1	194.89	198.68	196.78	5.32	5.62	5.47
B_2	197.77	203.90	200.84	5.76	5.91	5.84
SEm±	***0.46***	***0.43***	***0.32***	***0.019***	***0.016***	***0.012***
CD(P=0.05)	***1.43***	***1.32***	***0.92***	***0.059***	***0.048***	***0.036***
P_0	186.82	190.84	188.83	5.27	5.44	5.35
P_1	197.99	201.54	199.76	5.66	5.85	5.75
SEm±	***0.68***	***0.42***	***0.40***	***0.015***	***0.013***	***0.010***
CD(P=0.05)	***2.02***	***1.26***	***1.15***	***0.045***	***0.038***	***0.028***

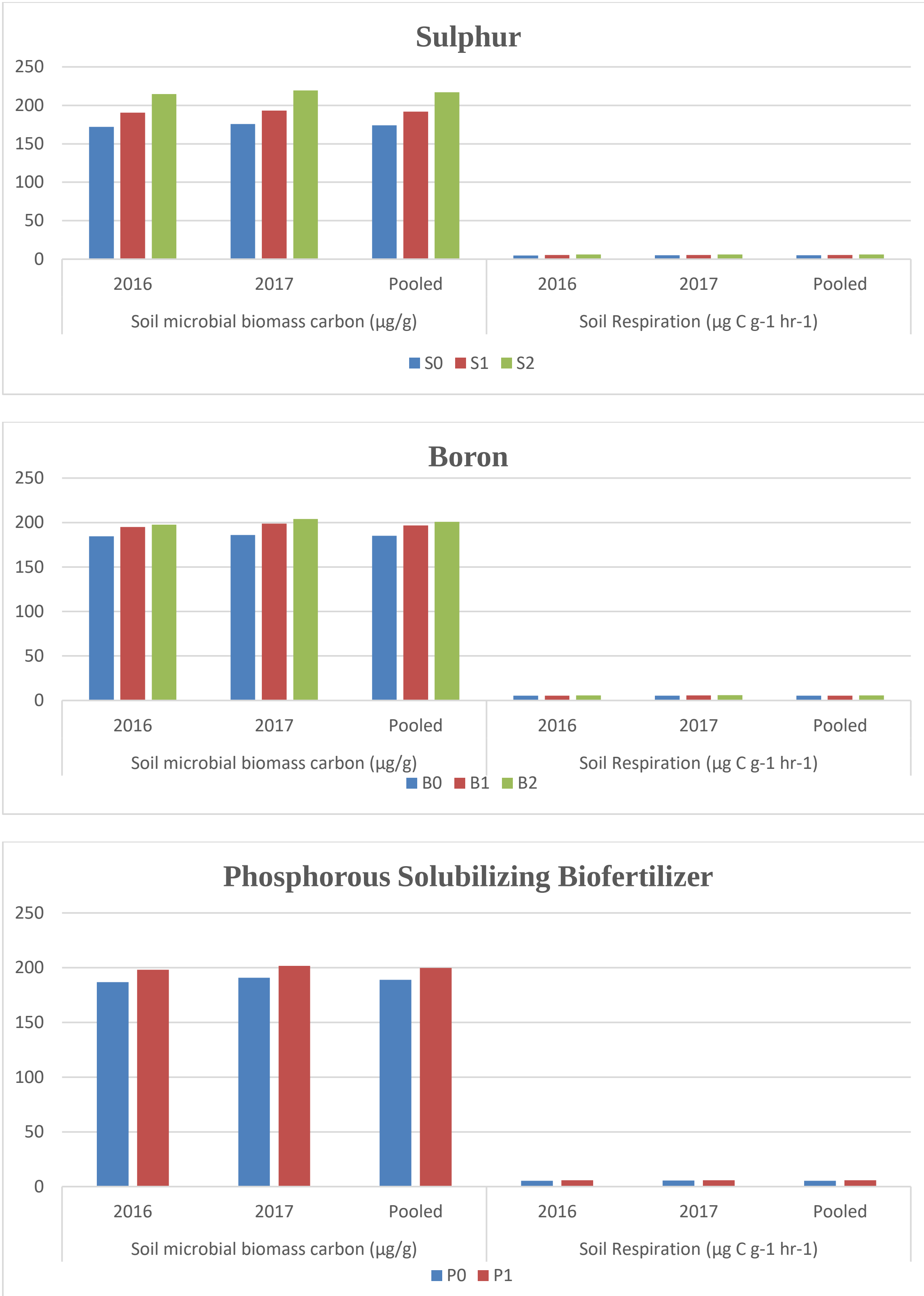


Fig. 10: Effect of sulfur, boron and phosphorus solubilizing biofertilizeron soil microbial biomass carbon and soil respiration

2016 and 2017 while in the pooled data it was 200.84 µg g^{-1} and 5.84 µg C g^{-1} hr^{-1}. The minimum soil microbial biomass carbon and soil respiration after harvest were recorded in B_0 as 184.55 µg g^{-1} and 185.99 µg g^{-1}, 5.32 µg C g^{-1} hr^{-1} and 5.40 µg C g^{-1} hr^{-1} during 2016 and 2017, respectively, with pooled data as 185.27 µg g^{-1} and 5.36 µg C g^{-1} hr^{-1}.

The soil microbial populations, rhizosphere metabolisms and the soil enzyme activities are improved with B application to soybean (Sun *et al.,* 2013). The increase in the soil respiration and soil microbial biomass carbon might be due to the improved plant nutrition which created an optimum root rhizosphere.

4.6.4.3. Effect of phosphorus solubilizing biofertilizer on soil microbial biomass carbon and soil respiration after harvest

As apparent from the data presented in Table 4.6.4 (a) and Fig. 10, phosphorus solubilizing biofertilizer was observed to have significant effect on the soil microbial biomass carbon and soil respiration. The results showed that application of phosphorus solubilizing biofertilizer (P_1) recorded significantly higher soil microbial biomass carbon and soil respiration as 197.99 µg g^{-1} and 201.54 µg g^{-1}, 5.66 µg C g^{-1} hr^{-1} and 5.85 µg C g^{-1} hr^{-1} as compared to P_0 which recorded 186.82 µg g^{-1} and 190.84 µg g^{-1}, 5.27 µg C g^{-1} hr^{-1} and 5.44 µg C g^{-1} hr^{-1} during 2016 and 2017, respectively. In the pooled data, the soil microbial biomass carbon and soil respiration recorded P_1 was 199.77 µg g^{-1} and 5.75 µg C g^{-1} hr^{-1} while P_0 had 188.83 µg g^{-1} and 5.35 µg C g^{-1} hr^{-1}, respectively.

Verma *et al.,* (2018) reported that application of *Rhizobium* + PSB along with 75% NPK and 25% N through vermicompost recorded significantly the highest soil microbial biomass carbon. Dhage *et al.* (2008) also revealed that microbial populations in soil are enhanced with biofertilizer (*Rhizobium* + PSB) application. Meena and Ghasolia (2013) observed maximum microbial population in soil when soybean seeds were inoculated with phosphate solubilizers. The increased soil microbial populations thus, eventually increased the soil microbial biomass carbon and soil respiration.

4.6.4.4. Effect of sulphur and boron interaction on soil microbial biomass carbon and soil respiration after harvest

The interaction effects of different treatments on the soil microbial biomass carbon and soil respiration were presented in Table 4.6.4 (b). The results revealed that the interaction between sulphur and boron have significant influence on the soil microbial biomass carbon and soil respiration after harvest. It has been observed that increasing the boron fertilization up to 2 kg B ha^{-1} at all levels of sulphur significantly increased the soil microbial biomass carbon and soil respiration than application of sulphur alone. The maximum soil microbial biomass carbon and soil respiration was observed in S_2B_2 which recorded 216.17 μg g^{-1} and 230.47 μg g^{-1}, 6.66 μg C g^{-1} hr^{-1} and 6.85 μg C g^{-1} hr^{-1} while the pooled data had 223.32 μg g^{-1} and 6.75 μg C g^{-1} hr^{-1} during 2016 and 2017, respectively. The lowest soil microbial biomass carbon and soil respiration was recorded in S_0B_0 as 168.29 μg g^{-1} and 170.47 μg g^{-1}, 4.69 μg C g^{-1} hr^{-1} and 4.87 μg C g^{-1} hr^{-1} while the pooled data had 169.38 μg g^{-1} and 4.78 μg C g^{-1} hr^{-1}, respectively during 2016 and 2017.

The increase in the soil respiration and soil microbial biomass carbon might be due to the improved plant nutrition which created an optimum root rhizosphere. Sarawgi *et al.* (2012) revealed that seed treatment with biofertilizers had significant effect on microbial population. Similar findings on soil microbial biomass carbon been reported by Verma *et al*. (2018) and Singh *et al*. (2015).

Table 4.6.4 (b) Effect of sulfur & boron, sulfur & phosphorus solubilizing biofertilizer and boron & phosphorus solubilizing biofertilizer interaction on soil microbial biomass carbon and soil repiration

Treatments	**Soil microbial biomass carbon (µg/g)**			**Soil Respiration(µg C g^{-1} hr^{-1})**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
S_0B_0	168.29	170.47	169.38	4.69	4.87	4.78
S_0B_1	172.36	177.69	175.02	4.63	5.06	4.84
S_0B_2	175.69	179.31	177.50	5.26	5.29	5.28
S_1B_0	178.90	180.98	179.94	5.50	5.52	5.51
S_1B_1	190.85	196.75	193.80	5.42	5.66	5.54
S_1B_2	201.46	201.92	201.69	5.35	5.59	5.47
S_2B_0	206.47	206.53	206.50	5.76	5.82	5.79
S_2B_1	221.45	221.60	221.53	5.91	6.13	6.02
S_2B_2	216.17	230.47	223.32	6.66	6.85	6.75
SEm±	***0.80***	***0.74***	***0.55***	***0.033***	***0.027***	***0.021***
CD(P=0.05)	***2.47***	***2.28***	***1.59***	***0.102***	***0.084***	***0.063***
S_0P_0	169.62	173.13	171.37	4.80	4.96	4.88
S_0P_1	174.61	178.51	176.56	4.92	5.19	5.06
S_1P_0	186.47	189.47	187.97	5.24	5.36	5.30
S_1P_1	194.33	196.97	195.65	5.61	5.82	5.71
S_2P_0	204.38	209.91	207.15	5.77	6.01	5.89
S_2P_1	225.01	229.15	227.08	6.45	6.52	6.49
SEm±	***1.18***	***0.73***	***0.69***	***0.026***	***0.022***	***0.017***
CD(P=0.05)	***3.49***	***2.18***	***1.99***	***0.077***	***0.066***	***0.049***
B_0P_0	177.78	179.27	178.53	5.17	5.25	5.21
B_0P_1	191.32	192.71	192.02	5.47	5.56	5.51
B_1P_0	191.15	193.99	192.57	5.13	5.37	5.25
B_1P_1	198.62	203.37	201.00	5.51	5.87	5.69
B_2P_0	191.54	199.25	195.39	5.51	5.71	5.61
B_2P_1	204.01	208.55	206.28	6.01	6.11	6.06
SEm±	***1.18***	***0.73***	***0.69***	***0.026***	***0.022***	***0.017***
CD(P=0.05)	***3.49***	***2.18***	***1.99***	***0.077***	***0.066***	***0.049***

4.6.4.5. Effect of sulphur and phosphorus solubilizing biofertilizer interaction on soil microbial biomass carbon and soil respiration after harvest

From Table 4.6.4 (b), it has become evident that the interaction between sulphur and phosphorus solubilizing biofertilizer had significant effect on soil microbial biomass carbon and soil respiration after harvest. Application of phosphorus solubilizing biofertilizer at all levels of sulphur was found to increase the soil microbial biomass carbon and soil respiration as compared to application of sulphur alone. The maximum soil biomass carbon and soil respiration has been observed with S_2P_1 which recorded 225.01 µg g^{-1} and 229.15 µg g^{-1}, 6.45 µg C g^{-1} hr^{-1} and 6.52 µg C g^{-1} hr^{-1} during 2016 and 2017 while the lowest was observed with S_0P_0 which recorded 169.62 µg g^{-1} and 17.13 µg g^{-1}, 4.80 µg C g^{-1} hr^{-1} and 4.96 µg C g^{-1} hr^{-1} during 2016 and 2017, respectively. In the pooled data, S_2P_1 recorded soil microbial biomass carbon and soil respiration of 227.08 µg g^{-1} and 6.49 µg C g^{-1} hr^{-1} while S_0B_0 recorded 171.37 and 4.88 µg C g^{-1} hr^{-1}, respectively. Improved plant nutrition through sulphur application along with phosphorus solubilizing biofertilizer might have favoured an optimal root rhizosphere which increased microbial populations and thereby increased the soil respiration and soil microbial biomass carbon. Dhage *et al*., (2008) also revealed that microbial populations in soil are enhanced with biofertilizer (*Rhizobium* + PSB) application.

4.6.4.6. Effect of boron and phosphorus solubilizing biofertilizer interaction on soil microbial biomass carbon and soil respiration after harvest

From the results presented in Table 4.6.4 (b), it has been revealed that application of increased level of boron along with phosphorus solubilizing biofertilizer as seed treatment significantly increases the soil microbial biomass carbon and soil respiration as compared to application of boron alone. The maximum soil microbial biomass carbon and soil respiration were recorded with

B_2P_1 as 204.01 μg g^{-1} and 208.55 μg g^{-1}, 6.01 μg C g^{-1} hr^{-1} and 6.11 μg C g^{-1} hr^{-1} during 2016 and 2017, respectively, with pooled data of 206.28 μg g^{-1} and 6.06 μg C g^{-1} hr^{-1}. The minimum soil microbial biomass carbon and soil respiration was observed with B_0P_0 which recorded 177.78 μg g^{-1} and 179.27 μg g^{-1}, 5.17 μg C g^{-1} hr^{-1} and 5.25 μg C g^{-1} hr^{-1} during 2016 and 2017, respectively, while in the pooled data it was 178.53 μg g^{-1} and 5.21 μg C g^{-1} hr^{-1}. From the pooled data it has been revealed that soil microbial biomass carbon as affected by B_1P_1 was significant over B_2P_0 and B_0P_1 was at par with B_1P_0. The soil respiration as affect by the interaction of B_1P_1 was found to be significant over B_2P_0.

The application of boron and seed inoculation with phosphorus solubilizing biofertilizer might have favoured an optimum root rhizosphere environment for microorganisms to thrive which resulted in increased soil respiration and soil microbial biomass carbon. Singh *et al.* (2015) observed that microbial inoculation increased the microbial biomass carbon over uninoculated control treatment due to increase in microbial cells in soil.

4.6.4.7. Effect of sulphur, boron and phosphorus solubilizing biofertilizer interaction on soil microbial biomass carbon and soil respiration after harvest

The interaction effect between sulphur, boron and phosphorus solubilizing biofertilizer on soil microbial biomass carbon and soil respiration has been presented in Table4.6.4 (c). The interaction between the different factors was found to have a significant influence on the soil microbial biomass carbon and soil respiration. It was observed that at all levels of sulphur, application of boron and phosphorus solubilizing biofertilizer significantly increased the microbial biomass carbon and soil respiration. The highest microbial biomass carbon and soil respiration was observed with $S_2B_2P_1$ which recorded 233.96 and 238.25 μg g^{-1},

Table 4.6.4 (c) Interation effect of sulfur, boron and phosphorus solubilizing biofertilizer on soil microbial biomass carbon and soil respiration

Treatments	Soil microbial biomass carbon (µg g^{-1})			Soil Respiration(µg C g^{-1} hr^{-1})		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
$S_0B_0P_0$	166.37	168.80	167.59	4.57	4.69	4.63
$S_0B_0P_1$	170.20	172.13	171.16	4.81	5.05	4.93
$S_0B_1P_0$	168.75	175.95	172.35	4.63	4.99	4.81
$S_0B_1P_1$	175.97	179.42	177.70	4.62	5.12	4.87
$S_0B_2P_0$	173.72	174.63	174.18	5.18	5.18	5.18
$S_0B_2P_1$	177.66	183.98	180.82	5.35	5.40	5.38
$S_1B_0P_0$	172.95	177.22	175.08	5.47	5.53	5.50
$S_1B_0P_1$	184.85	184.74	184.80	5.54	5.51	5.52
$S_1B_1P_0$	183.96	190.76	187.36	5.29	5.27	5.28
$S_1B_1P_1$	197.74	202.75	200.24	5.55	6.05	5.80
$S_1B_2P_0$	202.51	200.43	201.47	4.97	5.29	5.13
$S_1B_2P_1$	200.41	203.41	201.91	5.73	5.90	5.82
$S_2B_0P_0$	194.03	191.78	192.91	5.46	5.51	5.49
$S_2B_0P_1$	218.92	221.27	220.09	6.05	6.12	6.09
$S_2B_1P_0$	220.74	215.27	218.01	5.46	5.84	5.65
$S_2B_1P_1$	222.16	227.93	225.05	6.37	6.42	6.40
$S_2B_2P_0$	198.38	222.68	210.53	6.38	6.67	6.53
$S_2B_2P_1$	233.96	238.25	236.11	6.94	7.03	6.98
SEm±	***2.04***	***1.27***	***1.20***	***0.045***	***0.038***	***0.030***
CD(P=0.05)	***6.05***	***3.77***	***3.44***	***0.134***	***0.114***	***0.085***

and 6.94 7.03 μg C g^{-1} hr^{-1} during 2016 and 2017, respectively. The lowest microbial biomass carbon and soil respiration was recorded with $S_0B_0P_0$ as 166.37 and 168.59, and 4.57 μg g^{-1} and 4.69 μg C g^{-1} hr^{-1} during 2016 and 2017, respectively. In the pooled data, $S_2B_2P_1$ recorded the highest microbial biomass carbon and soil respiration as 236.11 μg g^{-1} and 6.98 μg C g^{-1} hr^{-1} while the lowest was observed with $S_0B_0P_0$ as 167.59 μg g^{-1} and 4.63 μg C g^{-1} hr^{-1}, respectively. From the pooled data, it is evident that the soil microbial biomass carbon as affected by $S_2B_1P_0$ and $S_2B_0P_1$ were at par with each other, while $S_1B_1P_1$, $S_1B_2P_0$ and $S_1B_2P_1$ were at par.

Application of sulphur and boron along with phosphorus solubilizing biofertilizer inoculation might have increased the microbial population through optimum root rhizosphere environment resulting in higher microbial biomass carbon and soil respiration. Dhage *et al*. (2008) also revealed that microbial populations in soil are enhanced with biofertilizer (*Rhizobium* + PSB) application. Singh *et al.* (2015) observed that microbial inoculation increased the microbial biomass carbon over uninoculated control treatment due to increase in microbial cells in soil.

4.7. Nutrient use efficiency

As shown in Table 4.7, during 2016 and 2017, the sulphur use efficiency (SUE) by soybean was observed to decrease with increase in level of sulphur application. This decreasing trend is in agrrement with von Leibig's Law of the Minimum which states that the most limiting factor determines the yield potentials (Giller *et al.,* 2002). The nutrient use efficiency was better at lower rate of sulphur application. Appliaction of 20 kg S ha^{-1} (S_1) shows better NUE, thereafter it significantly declined with application of 40 kg S ha^{-1} (S_2). The decline in SUE with increased dosage of S might due to the fact that plants grown in S deficient soil exhibit greater S sorption at lower doses of S.

As evident from Table 4.7, the boron use efficiency (BUE) by soybean was higher at 1 kg B ha^{-1} (B_1) and lower at 2 kg B ha^{-1} (B_2) during both the years. Thus, the loss of boron from the soil might be responsible for the decreased BUE with increment of B levels applied. Since plant nutritional demand of boron is limited, it may encounter greater losses and less utilization by the crops when applied in excess. The excess of applied B may not be absorbed by plant and can be lost decreasing the efficiency of fertilization with higher B rates. The present observation is in congruence with the observations of Byju *et al.* (2007) where the highest BUE was obtained with application of B at the rate of 1.0 kg ha^{-1}.

Table 4.7 Nutrient use efficiency of sulphur and boron

Treatments	Sulphur use efficiency (%)		
	2016	**2017**	**Pooled**
S_0 (0 kg S ha^{-1})	-	-	-
S_1 (20 kg S ha^{-1})	14.10	15.90	15.00
S_2 (40 kg S ha^{-1})	12.88	13.50	13.18
	Boron use efficiency (%)		
	2016	**2017**	**Pooled**
B_0 (0 kg B ha^{-1})	-	-	-
B_1 (1 kg B ha^{-1})	3.39	3.74	3.84
B_2 (2 kg B ha^{-1})	3.16	3.23	3.20

CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The research investigation entitled **"Effect of sulphur, boron and phosphorus solubilizing biofertilizer on soybean (*Glycine max* L. *Merril*) under foothill condition of Nagaland"** was carried out during the *kharif* season of 2016 and 2017 in the experimental research farm of Nagaland University, School of Agricultural Sciences and Rural Development (SASRD), Medziphema campus. The main findings of the investigations are summarized below:

1. Application of sulphur and boron alone significantly influenced the growth parameters in soybean however, when applied together in conjunction with seed treatment of phosphorus solubilizing biofertlizers further enhances the growth attributing characters in soybean. Application of Sulphur @ 40 kg ha^{-1}, Boron @ 2kg ha^{-1} and seed treatment with Phosphorus Solubilizing Biofertilizer @ 200g/10kg seeds significantly recorded the highest growth attributing parameters such as plant height, number of leaves $plant^{-1}$, number of branches $plant^{-1}$, number of nodules $plant^{-1}$ and plant dry matter whereas the lowest was recorded in the control.

2. Significantly higher yield attributing parameters such as number of pods $plant^{-1}$, number of filled pods $plant^{-1}$, number of seeds pod^{-1} and seed test weight were obtained when Sulphur @ 40 kg ha^{-1}, Boron @ 2kg ha^{-1} along with seed treatment with Phosphorus Solubilizing Biofertilizer @ 200g/10kg were applied as compared to other treatment combination including control treatment. Synergistic interaction effect between sulphur and boron on the yield attributing parameters of soybean was observed during the two years research investigation.

3. Individual application of Sulphur, Boron significantly improved the biological yield, stover yield, seed yield and harvest index. Seed treatment of soybean with Phosphorus Solubilizing Biofertilizer influenced the biological yield, stover yield, seed yield except the harvest index. Synergistic interaction effect between the different treatment factors was observed. The yield of soybean was observed to increase with increasing dosage of fertilizer and the highest biological yield of 53.21 q ha^{-1}, seed yield of 21.76 q ha^{-1}and stover yield of 31.45 q ha^{-1} was recorded with application of Sulphur @ 40 kg ha^{-1}, Boron@ 2kg ha^{-1} and seed treatment with Phosphorus Solubilizing Biofertilizer @ 200g/10kg, the control plot recorded the lowest yield.

4. The nutrient content of N, P, K, S and B in stover was significantly influenced by the application of Sulphur, Boron and Phosphorus Solubilizing Biofertilizer individually. The nutrient concentration in the stover increased when the levels of Sulphur and Boron applications were increased. The interaction between Suplhur and Boron were found to have significant influence on the N, K, S and B content in soybean stover. Combined application of 40 kg S ha^{-1} and 2 kg B ha^{-1} showed maximum content of these nutrients in the stover.

5. It was observed that increasing the levels of sulphur and boron application alone increased the nutrient content in seeds of soybean. Seed treatment with Phosphorus Solubilizing Biofertilizer @ 200 g 10 kg^{-1} seeds was beneficial for increasing the nutrient content in seeds of soybean. Significantly higher N, P, K, S and B was obtained in seeds when 40 kg S ha^{-1} was applied and the same was true with application of 2 kg B ha^{-1}. There was no significant interaction effect between Sulphur and Boron on

N, P, K and S content except on the B content in seeds where synergistic interaction effect between sulphur and boron contributed to significant increase in B content in seeds.

6. Fertilization with Sulphur @ 40 kg ha^{-1}, Boron @ 2kg ha^{-1} and seed treatment with Phosphorus Solubilizing Biofertilizer @ 200g/10kg seeds either alone or in combination significantly increased the nutrient uptake by stover. The increase in nutrient uptake was more pronounced when applied together indicating synergistic interaction effect between the different treatment factors. The uptake of nutrients by stover increases with increase levels of fertilizer application and the highest N, P, K, S, and B uptake was obtained from combined application of Sulphur @ 40 kg ha^{-1}, Boron @ 2kg ha^{-1} and seed treatment with Phosphorus Solubilizing Biofertilizer @ 200g/10kg seeds whereas the lowest was recorded in the control.

7. Plants receiving Sulphur @ 40 kg ha^{-1}, Boron @ 2kg ha^{-1} along with seed treatment with Phosphorus Solubilizing Biofertilizer @ 200g/10kg seeds shows higher uptake of N, P, K, S and B by seeds. The improvement in the uptake of nutrients due to higher dry matter production, seed and haulm yield might be as a result of improved nutrient availability through fertilization. Synergistic interaction was found to exist between the different treatment factors.

8. The highest total nutrient uptake of 209.77 kg N ha^{-1} 18.58 kg P ha^{-1}, 101.79 kg K ha^{-1}, 16.46 kg S ha^{-1} and 137.70 g B ha^{-1} was obtained with combined application of Sulphur @ 40 kg ha^{-1}, Boron @ 2kg ha^{-1} along with seed treatment with Phosphorus Solubilizing Biofertilizer @ 200g/10kg seeds. Well developed root system, higher matter production,

seed and stover yield as a result of improved nutrient availability might be responsible for higher nutrient uptake by soybean.

9. Sulphur fertilization had significant influence on the protein content, protein yield as well as oil content and yield indicating the importance of sulphur in oil seeds production. The increase in protein content, protein yield, oil content and yield were significantly higher with higher dose of S application @ 40 kg ha^{-1}. The interaction between the different treatment factors did not have any significant influence on protein and oil content. However, the protein yield and oil yield were significantly increased by the interaction between Sulphur, Boron and Phosphorus Solubilizing Biofertilizer. Though the interaction effect on protein content was non-significant, the significant increased in protein yield might be due to the fact that the calculation on protein yield was based on seed yield. The significant increased in oil yield could be linked to the increased seed yield with sulphur and boron fertilization and application of PSB.

10. Sulphur application was observed to have increased the S status of post harvest soil. Boron fertilization has increased the B content of the soil after harvest. Seed treatment with Phosphorus Solubilizing Biofertilizer must have solubilizes the insoluble inorganic phosphate present in the soil thereby increases the P content of post harvest soil. The available N in the post harvest soil was increased as a result of enhanced root nodulation and N_2 fixation through improved nutrient availability. The soil fertility status was improved with application of Sulphur @ 40 kg ha^{-1}, Boron @ 2kg ha^{-1} and seed treatment with Phosphorus Solubilizing Biofertilizer @ 200g/10kg seeds through balanced application of nutrients to the plants.

11. It was observed that the pH of the soils tends to decreases with increasing dosage of fertilizers though the decline was non-significant. However, the continuous use of chemical fertilizers may decrease the soil pH in the long run when applied indiscriminately and aggravates the soil problems.

12. The soil microbial biomass carbon and soil respiration was highest with the application of Sulphur @ 40 kg ha^{-1}, Boron @ 2kg ha^{-1} and seed treatment with Phosphorus Solubilizing Biofertilizer @ 200g/10kg seeds whereas the lowest was recorded in the control. The soil microbial populations, rhizosphere metabolisms and the soil enzyme activities were improved with S and B application to soybean. Furthermore, the addition of Phosphorus Solubilizing Biofertilizer increased the soil microbial population thereby increasing the soil microbial biomass carbon and soil respiration.

13. The nutrient use efficiency of sulphur and boron were observed to be higher at lower doses which thereafter declined with increased levels of sulphur and boron application. This suggests that plant grown in S and B deficient soils exhibits higher sorption of sulphur and boron at lower doses. The highest nutrient use efficiency was observed with application of 20 kg S ha^{-1} and 1 kg B ha^{-1}. This suggests that addition of chemical fertilizers in excess will only decline the nutrient use efficiency and renders the operation uneconomical.

Conclusion

From the observations obtained from research investigation, we can draw the conclusion that application of RDF of NPK along with 40kg S, 2kg B and seed treatment with PSB@ 200g/10kg seeds was found to be beneficial for increasing the growth, yield and quality attributes of soybean under foothill condition of

Nagaland. The uptake of nutrients by soybean was found to increase with increasing application of nutrients and application Sulphur @ 40kg ha^{-1}, Boron @ 2kg ha^{-1} and PSB @ 200g/10kg seeds was found to be optimum resulting in higher yield. Soybean responds well to the increased application of Sulphur and Boron along with seed treatment with PSB. The soil fertility status and biological parameters were improved through balanced application of nutrients. The optimum dosage of fertilizers should be applied to avoid loss of nutrients and improve nutrient use efficiency. Inclusion of secondary nutrient sulphur and micronutrient boron in the fertilizer recommendation along with the use of biofertilizers such as phosphorus solubilizing biofertilizer will contribute towards profitable soybean production.

REFERENCES

A. O. A. C. 1960. Official Methods of analysis (18th edition). Association of Official Agricultural Chemists, Washington.

Akter F, Islam M N, Shamsuddoha A T M, Bhuiyan M S I and Shilpi S. 2013. Effect of phosphorus and sulphur on growth and yield of soybean (*Glyine max* L.). *International Journal of Bio-resource and Stress Management* **4**(4): 556-561.

Argaw A. 2012. Evaluation of co-inoculation of *Bradyrhizobium japonicum* and phosphate solubilizing *Pseudomonas ssp.* effect on soybean (*Glycine max* L. Merr.) in Assossa area. *Journal of Agricultural Science and Technology* **14**: 213-224.

Awal M A, Rashid M H O and Rahman M M. 2020. Effect of Agronomic Biofortification of Sulphur and Boron on the Growth and Yield of Mustard (*Brassica campestris* L.) Crop. *Asian Soil Research Journal* pp. 1-8.

Barman M, Shukla L M, Datta S P and Rattan R K. 2014. Effect of applied lime and boron on the availability of nutrients in an acid soil. *Journal of Plant Nutrition* **37**: 357-373.

Baruah T C and Barthakur H P. 1997. *A textbook of Soil Analysis*. Vikas Publ. House Pvt. Ltd., New Delhi.

Biswas B R, Begum A, Sharmin S and Choudhury A K. 2006. Effect of sulphur and molybdenum on nodulation, protein and nutrient content of soybean cv. Shohag. *Journal of Bangladesh Agricultural University* **4**(1): 33-42.

Black C A. 1965. Methods of Soil Analysis. *American Society of Agronomy, Inc, Publisher, Madison, Wisconsin, USA*, pp 171–175.

Brar B S, Jagdeep S and Benipal D S. 2010. Response of soybean to different levels of phosphorus and sulphur in alluvial soils of Punjab. *Indian Journal of Ecology* **37**(1): 56-59.

Bray R H and Kurtz L T. 1945. Determination of total organic and available forms of phosphorus in soils. *Soil Science* **59**: 39–45.

Byju, G., Nedunchezhiyan, M. and Naskar, S. K. 2007. Sweet potato response to boron application on an Alfisol in the sub humid tropical climate of India. *Communications in Soil Science and Plant Analysis.* **38**: 2347-2356.

Cakmak I and Omheld V R. 1997. Boron deficiency induced impairments of cellular functions in plants. *Plant and Soil* **193**: 71-83.

Chaithra M C and Hebsur N S. 2018. Growth and yield of soybean (*Glycine max* L.) as influenced by boron nutrition in a vertisol. *International Journal of Current Microbiology and Applied Sciences* **7**(11): 3298-3300.

Chandel A S, Pandey K N and Saxena S C. 1989. Symbiotic nitrogen benefits by nodulated soybean (*Glycine max* (L.) Merrill) to interplanted crop in Northern India. *Tropical Agriculture* **66**(1): 73-77.

Chapman D H and Pratt P F. 1961. Methods of analysis of soils, plants and water. University of California, Riverside, Division of Agriculture Science pp 309.

Chapman H D. 1965. CEC by ammonium saturation. *American Journal of Agronomy* **9**: 891–901.

Chatterjee R and Bandyopadhyay S. 2017. Effect of boron, molybdenum and biofertilizers on growth and yield of cowpea (*Vigna unguiculata* L. Walp.)

in acid soil of eastern Himalayan region. *Journal of the Saudi Society of Agricultural Sciences* **16**: 332-336.

Chauhan S, Titov A and Tomar D S. 2013. Effect of potassium, sulphur and zinc on growth, yield and oil content in soybean (*Glycine max* L.) in vertisols of Central India. *Indian Journal of Applied Research* **3**(6): 489-491.

Chaurasia A K, Richharia G P and Chaurasia S. 2009. Effect of doses and sources of sulphur on growth, nodulation, physiological characters and yield of soybean. *Research on Crops* **10**(1): 35-37.

Chesnin L and Yien C H. 1950. Turbimetric determination of available sulphates. *Soil Science Society of America Proceedings* **28**: 149–151.

Choudhary P, Jhajharia A and Kumar R. 2014. Influence of sulphur and zinc fertilization on yield, yield components and quality traits of soybean (*Glycine max* L.). *The Bioscan* **9**(1): 137-142.

Devi K N, Singh L N K, Devi T S, Devi H N, Singh T B, Singh K K and Singh W M 2012. Response of soybean (*Glycine max* L. Merrill) to sources and levels of phosphorus. *Journal of Agricultural Science.* **4**(6): 44 – 53.

Devi K N, Singh L N K, Singh M S, Singh S B and Singh K K. 2012. Influence of sulphur and boron fertilization on nutrient uptake and economics of soybean (*Glycine max*) under upland conditions. *Journal of Agricultural Science* **4** (4): 1-10.

Devi K N, Singh T B, Athokpam H S, Singh N B and Shamurailatpam D. 2013. Influence of inorganic, biological and organic manures on nodulation and yield of soybean (*Glycine max* L. Merril) and soil properties. *Australian Journal of Crop Science* **7**(9): 1407 – 1415.

Dhage S J and Kachhave K G. 2008. Effect of dual inoculation of *rhizobium* and PSB on yield, nutrient content, availability of nutrient contents and quality of soybean [*Glycine max* (L.) Merrill]. *An Asian Journal of Soil Science* **3**(2): 272-276.

Dhage S J, Kachhave K G and Shirale S T. 2008. Effect of biofertilizers on nodulation, uptake of nutrients, yield and economics of soybean (*Glycine max* L. Merril) production in vertisol. *Asian Journal of Soil Science* **3**(2): 299-303.

Dhage S J, Patil V D and Patange M J. 2014. Effect of various levels of phosphorus and sulphur on yield, plant nutrient content, uptake and availability of nutrients at harvest stages of soybean [*Glycine max* (L.)]. *International Journal of Current Microbiology and Applied Sciences* **3** (12): 833-844.

Dible W T, Truog E and Berger K C. 1954. Boron determination in soils and plants: Simplified curcumin procedure. *Analytical Chemistry* **26**: 418-421.

Diep C N, So D B, Trung N B and Lam V H. 2016. Effect of rhizobia and phosphate solubilizing bacteria on soybean (*Glycine max* L. Merr.) cultivated on ferrasols of Daklak province, Vietnam. *World Journal of Phermacy and Pharmaceutical Sciences* **5**(4): 318-333.

Farhad I S M, Islam M N, Hoque S and Bhuiyan M S I. 2010. Role of potassium and sulphur on growth, yield and oil content of soybean (*Glycine max* L.). *Academic Journal of Plant Sciences* **3**(2): 99-103.

Fatima Z, Zia M and Chauhary M F. 2006. Effect of rhizobium and phosphorus on growth of soybean (*Glycine max*) and survival of rhizobium and P solubilizing bacteria. *Pakistan Journal of Botany* **38**(2): 459-464.

Franco A A. 1978. Contribution of the legume-rhizobium symbiosis to the ecosystem and food production. *Limitations and Potentials for Biological Nitrogen Fixation in the Tropics* pp 65-74.

Gaines, T. P. and Mitchell, G. A. 1979. Boron determination in soils and plants by the azomethine-H method. *Communication in Soil Science and Plant Analysis*. **10**: 1099-1108.

Game B C, Ilhe B M, Pawar V S and Khandagale P P. 2020. Effect of Azotobacter, Phosphate Solubilising Bacteria and Potash Mobilising Bacteria Inoculants on Productivity of Wheat (*Triticum aestivum* L.). *International Journal of Current Microbiology and Applied Sciences* **9**(3): 2800-2807.

Ganeshamurthy A N and Reddy K S. 2000. Effect of integrated use of farmyard manure and sulphur in a soybean and wheat cropping system on nodulation, dry matter production and chlorophyll content of soybean on Swell-Shrink soils of Central India. *Journal of Agronomy and Crop Science* **185**: 91-97.

Ganeshamurthy A N. 1996. Critical plant sulphur content and effect of S application on grain and oil yield of rainfed soybean in vertic ustochrepts. *Journal of Indian Society of Soil Science* **44**: 290-294

Ganie M A, Akhter F, Najar G R and Bhat M A. 2014 Influence of sulphur and boron on nutrient content and uptake of French bean (*Phaseolus vulgaris* L.) under inceptisols of North Kashmir. *African Journal of Agricultural Research* **9**(2): 230-239.

Giller, K. E., Cadisch, G. and Palm, C. 2002. The North-South Divide! Organic wastes or resources for nutrient management? *Agronomie*. **22**: 645-653.

Gomez K A and Gomez A A. 1984. Statistical procedures for agricultural research. *Wiley Interscience Publication*, Second edition pp 139–153.

Gupta S C, Namdeo S L and Paliwal K K. 1998. Effect of P levels and microbial inoculants on symbiotic traits, N and P uptake, quality and yield of rainfed chickpea (*Cicer arietinum* L.) *In-Proceedings of 3rd European Conference on Grain Legumes. Vallodolid, Spain*, pp 418 -419.

Gyaneshwar P, Nareshkumar G and Parckh L D. 1998. Effect of buffering on the phosphate solubilizing ability of microorganisms. *World journal of Microbiology and Biotechnology* **14**: 669 – 673.

ICAR. 2018. Soybean monitor/market watch. *ICAR-Indian Institute of Soybean Research.* pp 1-9.

Imade S R, Kubde K J, Thakur M R and Gudade B A. 2010. Response of biofertilizer under different levels of phosphorus and sulphur to yield, nutrient uptake and quality of soybean. *Annals of Plant Physiology* **24**(1): 21-24.

Ismail S, Jani S J and Kosare C S. 2013. Interaction effect of sulphur and boron on yield, nutrient uptake and quality of soybean grown on Vertisol. *An Asian Journal of Soil Sience* **8**(2): 275-278.

Jackson M L. 1973. *Soil Chemical Analysis,* Prentice Hall of India Private Limited, New Delhi.

Jamal A, Fazil I S, Ahmad S, Abdin M Z and Yun S J. 2005. Effect of sulphur and nitrogen application on growth characteristics, seed and oil yields of soybean cultivars. *Korean Journal of Crop Science* **50**(5): 340 – 345.

Jamal A, Moon Y S and Abdin M Z. 2010. Sulphur – a general overview and interaction with nitrogen. *Australian Journal of Crop Science* **4**(7): 523-529.

Kader A E and Mona G. 2013. Effect of sulfur application and foliar spray with zinc and boron on yield, yield components, and seed quality of peanut (*Arachis hypogaea* L.). *Research Journal of Agriculture and Biological Sciences* **9**(4): 127-135.

Kalaiyarasan C, Tamizhselvan D, Jawahar S, Ezhilkumar S, Suseendran K, Madhavan S and Ramesh S. 2020. Effect of sulphur and boron on hybrid sunflower. *Plant Archives* **20** (1): 741-746.

Kamboj N and Malik R S. 2018. Influence of phosphorus and boron application on yield, quality, nutrient content and their uptake by green gram (*Vigna radiate* L.). *International Journal of Current Microbiology and Applied Sciences* **7**(3): 1451-1458.

Khaswa L K, Dubey R K, Singh S and Tiwari R C. 2014. Growth, productivity and quality of soybean (*Glycine max* L. Merril) under different levels and sources of phosphorus and plant growth regulators in sub humid Rajasthan. *African Journal of Agricultural Research* **9**(12): 1045-1051.

Kothari M L and Jethra J K. 2002. Response of wheat to sulphur application in loamy sand soil. *Annals of Arid Zone* **41**: 191-194.

Kumar A. 2007. A study of consumer attidudes and acceptability of soy food in Ludhiana. *MBA research project report, Department of business management, Punjab Agricultural University, Ludhiana, Punjab.*

Kumar B K, Ismail S, Manasa K and Pawar A. 2017. Enhancement of nutrient availability in soil using microbial cultures in soybean grown on vertisol. *International Journal of Current Microbiology and Applied Sciences* **6**(5): 2802-2807.

Kundu D, Khanan R, Thingujam U, Saha S and Hazra G C. 2016. Boron nutrition of crops in releation to yield and quality – a review. *Agricultural research and Technology: Open Access Journal* **2**(3): 1-5.

Lakshman K, Vyas A K, Shivakumar B G and Rana D S. 2015. Effect of levels and time of sulphur application on growth and quality of soybean (*Glycine max*). *Indian Journal of Agronomy* **60**(1): 121-125.

Lalitlanmawia L, Singh A K and Sharma S K. 2005. Effect of phosphorus and molybdenum nutrition on growth, yield and nutrient content of soybean in an acid alfisol of Nagaland. *Annals of Agricultural Research and News Series* **26**(4): 591-595.

Layek J, Shivakumar B G, Rana D S, Gangaiah B, Lakshman K and Paramanik B. 2014. Growth, nodulation, physiological indices and yield of soybean as influenced by sulphur and boron nutrition. *The Bioscan* **9**(4): 1389-1393.

Longkumer L T, Singh A K, Jamir Z and Kumar M. 2017. Effect of sulphur and boron nutrition on yield and quality of soybean (*Glycine max* L.) grown in an acid soil. *Communications in Soil Science and Plant Analysis* **48** (4): 405-411.

MacFayden A. 1970. Soil metabolism in relation to ecosystem energy flow and to primary and secondary production. In: International Biome Project (ed) Methods of study in soil ecology, UNESCO, Phillipson, pp 167-172.

Mahmoodi B, Mosavi A A, Daliri M S and Namdari M. 2013. The evaluation of different values of phosphorus and sulphur application in yield, yield components and seed quality characteristics of soybean (*Glycine max* L.). *Advances in Environmentl Biology*. **7**(1): 170-176.

Majumdar B, Venkatesh M S, Lal B and Kumar K. 2001. Response of soybean (*Glycine max*) to phosphorus and sulphur in acid alfisol of Meghalaya. *Indian Journal of Agronomy* **46**(3): 500-505.

Malewar G V, Kate S D, Waiker S L and Ismail S. 2001. Interaction effect between zinc and boron on yield, nutrient uptake and quality of mustard (*Brassica juncea* L.) on a Typic Haplustert. *Journal of the Indian Society of Soil Science* **49**: 763-765.

Marschner H. 1995. Mineral nutrition of higher plants. 2nd ed. Academic Press, San Diego, California.

Meena S and Ghasolia R P. 2013. Effect of phosphate solubilizers and FYM on microbial population of soybean field (*Glycine max* L. Merril). *The Bioscan* **8**(3): 965-968.

Mengel K, Kirkby E A, Kosegarten H and Appel T. 2001. Principles of plant nutrition, vol 5. Springer Netherlands. pp 1-849.

Mere V. 2016. Effect of lime, farmyard manure and fertilizers on growth, yield and quality of soybean (*Glycine max* L. Merril) in acid soils of Nagaland.

Ph. D. Thesis, Nagaland University, School of Agricultural Sciences and Rural Development, Medziphema Campus, India.

Meshram D, Pagar P C, Kuchanwar O D, Moharkar R and Raut V. 2017. Effect of sulphur and boron on quality, nutrient content and uptake and residual soil fertility in soybean. *Journal of Soils and Crops* **27**(1): 158-161.

Modhavadiya V L, Solanki M S, Hirpara D V, Jadeja A S and Ranpariya V S. 2018. Effect of sulphur and boron on yield of summer sesamum (*Sesamum indicum* L.) under medium black calcareous soils of south Saurashtra region of Gujarat. *International Journal of Chemical Studies* **6**(1): 378-380.

Naaz S and Hasan Z. 2020. Effect of biofertilizers [*Azotobacter* & PSB] on different growth parameters of soybean (*Glycine max* L.) in the presence of *Rhizobium japonicum*. *Plant Archives* **20**(1) 2341-2344.

Nagar G K, Dashora L N, Suman C S, Meena R K, Choudhary G L and Teli S K. 2018. Effect of microbial inoculation and sulphur on soybean growth and yield. *International Journal of Pure and Applied Bioscience* **6**(1): 1083-1087.

Najar G R, Singh S R, Akhtar F and Hakeem S A. 2011. Influence of sulphur level on yield, uptake and quality of soybean (*Glycine max*) under temperate conditions of Kashmir valley. *Indian Journal of Agricultural sciences* **81** (4): 340-343.

Pal D and Phogat V K. 2005. Effect of deep tillage and gypsum on yield, and N, P, K and S uptake by mustard. *Journal of Indian Society of Soil Science* **53**(1): 134-136.

Parakhia D V, Parmar K B, Vekaria L C, Bunsa P B and Donga S J. 2016. Effect of various sulphur levels on dry matter, yield and yield attributes of soybean [*Glycine max* (L.)] varieties. *The Ecoscan* **10**(1&2): 51-54.

Patel A R and Zinzala V J. 2018. Effect of sulphur and boron on nutrient content and uptake by summer groundnut (*Arachis hypogeal* L.). *The Pharma Innovation Journal* **7**(4): 47-50.

Pindkurwar K S, Awasarmal V B, Gokhale D N and Pawar S U. 2015. Growth and yield of soybean (*Glycine max* L. Merill) as influenced by carrier based and liquid bio-inoculants. *InternationalJournal of Tropical Agriculture* **33** (4): 2665 - 2668.

Piper C S. 1966. Soil and Plant Analysis, *Hans Publishers* pp 368.

Rahman M H H, Arima Y, Watanabe K and Sekimoto H. 1999. Adequate range of boron nutrition is more restricted for root nodule development than for plant growth in young soybean (*Glycine max* L.) plant. *Soil Science and Plant Nutrition* **42**(2): 287-296.

Rahman M A, Karim A J M S, Solaiman A R M, Islam A and Zareen I. 2004. Effect of inoculum, boron and variety on nutrients content and their uptake by plant tops of soybean. *Journal of Agriculture* **2**: 13-21.

Raja D and Takankhar V G. 2017. Growth characters of soybean (*Glycine max*) as effect by liquid biofertilizers (*Bradyrhizobium* and PSB). *International Journal of Pure and Applied Bioscience* **5**(5): 101-111.

Rajendran K, Amanullah M M, Vijayapuri K. 2012. Influence of sulphur and boron on yield attributes and yield of soybean. *Madras Agricultural Journal* **97**(1-3): 65-67.

Ram H, Singh G and Aggarwal N. 2014. Grain yield, nutrient uptake, quality and economics of soybean (*Glycine max*) under different sulphur and boron levels in Punjab. *Indian Journal of Agronomy* **59** (1): 101-105.

Rana M, Lahoty P and Sharma N. 2014. Effect of PSB, rhyzobium and phosphorus levels on growth parameters and benefit cost ratio of soybean (*Glycine max* L. Merr.). *Journal of Industrial Pollution Control* **30** (2): 263-266.

Rathod P K, Salvi V G, Pawar S S and Chavan K N. 2016. Effect of lime, zinc and boron on yield and uptake of micronutrients by soybean. *An Asian Journal of Soil Science* **11**(2): 290-296.

Ravi S, Jadhav R L and Sidramappa. 2017. Response of soybean to sulphur and boron nutrition in Northern Karnataka, India. *International Journal of Current Microbiology and Applied Sciences* **12**: 3426-3432.

Reddy G R, Sudhakar N, Srinivasarao C and Kokate K D. 2014. Status of sulphur and soybean response to sulphur application in rainfed conditions. *Indian Journal of Fertilisers* **10**(4): 38-41.

Richards L A. 1954. Diagnosis and improvement of saline and alkali soils. *Agricultural Handbook No*. **60**, USDA, Washington.

Ross J R, Slaton N A, Brye K R and Delong R E. 2006. Boron fertilization influences on soybean yield and leaf and seed boron concentrations. *Agronomy Journal* **98**: 198-205.

Sahebagouda , Chikkaramappa T and Basavaraja P K. 2019. Effect of Varied Levels of Sulphur and Sources of Organics on Growth, Yield Parameters and Economics of Soybean (Glycine max L.) in Alfisols of Karnataka. *International Journal of Pure and Applied Bioscience* **7**(3): 141-148.

Sandeep A R, Joseph S and Jisha M S. 2008. Yield and nutrient uptake of soybean (*Glycine max* (L) Merr) as influenced by phosphate solubilizing microorganisms. *World Journal of Agricultural Sciences* **4**(S): 835-838.

Sangale R V and Sonar K R. 2004. Yield and quality of soybean as influenced by sulphur application. *Journal of Maharashtra Agriculture Universities* **29**(1): 117-118.

Sarawgi S K, Shrikant C, Tiwarp A and Bhoi S. 2012. Effect of phosphorus application along with PSB, *Rhizobium* and VAM on P fractionation and productivity of soybean (*Glycine max*). *Indian Journal of Agronomy* **57**(1): 55-60.

Sarker S K, Chowdhury M A H and Zakir H M. 2002. Sulphur and boron fertilization on yield quality and nutrient uptake by Bangladesh Soybean-4. *Journal of Biological Sciences* **2**(11): 729-733.

Satya M S S C and Swami S. 2021. Nutrient uptake by black gram (*Vigna mungo* L. Hepper) as influenced by phosphorus and boron fertilization in acid Inceptisol of Meghalaya. *International Journal of Agricultural and Applied Sciences* **2**(1):118-122.

Saxena S C and Nainwal R C. 2010. Effect of sulphur and boron nutrition on yield, yield attributes and economics of soybean. *Soybean Research* **8**: 7-12.

Sentimenla, Singh A K and Singh S. 2012. Response of soybean to phosphorus and boron fertilization in acidic upland soil of Nagaland. *Journal of the Indian Society of Soil Science* **60** (2): 0-0.

Sentimenla. 2020. Response of Soybean (Glycine max L. Merril) to Biofertilizer and FYM in the Jhum Fields under Zunheboto Districts of Nagaland, India. *International Journal of Current Microbiology and Applied Sciences* **9**(6): 126-130.

Sharma A, Sharma S and Gill P P S. 2014. Influence of nitrogen and sulphur appliacations on nutrient uptake, protein content and yield parameters of soybean. *Indian Journal of Plant Sciences* **3**(2): 31-34.

Sharma O P and Singh G D. 2005. Sulphur in conjunction with growth substances on productivity of clusterbean (*Cyamopsis tetragonoloba*) and their residual effect on barley (*Hardeum vulgare*). *Indian Journal of Agronomy* **50**(1): 16 – 18.

Shinde R N, Karanjikar P N and Gokhale D N. 2015. Effect of different levels fertilizer and micronutrients on growth, yield and quality of soybean. *Journal Crop and Weed* **11**(1): 213 – 215.

Shivran R K, Rokadia P and Kumar R. 2012. Phosphorus and sulphur with P-solubilizing bacterial inoculation enhanced the quality and yield of soybean. *Madras Agricultural Journal* **99**(1-3): 68-72.

Shrivastava U K, Rajput R L and Diwivedi M L. 2000. Response of soybean-mustard cropping system to sulphur and biofertilizers on farmer's field. *Legume Research* **23**: 277-278.

Singh A V, Shah S and Prasad B. 2010. Effect of phosphate solubilizing bacteria on plant growth promotion and nodulation in soybean (*Glycine max* L. Merr.) *Journal of Hill Agriculture* **1**(1): 35-39.

Singh C, Singh P and Singh R. 2003. *Modern Techniques of Raising Field crops.* Oxford and IBH Publishing Co. Pvt. Ltd. pp 273.

Singh M, Kumar N, Kumar S and Lal M. 2015. Effect of co-inoculation of *B. japonicum*, PSB and AM fungi on microbial biomass carbon, nutrient uptake and yield of soybean (*Glycine max* L. Merril). *Agriways* **3**(1): 14-18.

Singh M, Singh V P and Reddy K S. 2001. Effect of integrated use of fertilizer nitrogen and farmyard manure or green manure on transformations of N, K and S and productivity of ricewheat system in Vertisol. *Journal of the Indian Society of Soil Science* **49**: 430-434.

Singh Y V, Singh D K, Sharma P K, Singh R K and Singh P. 2014. Interaction effect of phosphorus and sulphur on the growth, yield and mineral composition of mungbean (*Vigna radiate* L. Wilzeck). *Journal of the Indian Society of Soil Science* **62**(2): 179-183.

Son T T N, Diep C N and Giang T T M. 2006. Effect of *Bradyrhizobia* and phosphate solubilising bacteria application on soybean in rotational system in the Mekong delta. *Omonrice* **14**: 48-57

Sree D R S. 2020. Role of sulphur in pulse crops: A review. *International Journal of Chemical Studies* **8**(6): 2302-2307.

Srivastava T K, Ahlawat I P S and Panwar J D S. 1998. Effect of P, Mo and biofertilizers on productivity of pea (*Pisum sativa* L.). *Indian Journal of Plant Physiology* **3**: 237-239.

Statistical Handbook of Nagaland. 2017. Department of Economics and Statistics, Government of Nagaland. https://cdn.s3waas.gov.in pp 24.

Subbiah B V and Asija G L. 1956. A rapid procedure for the determination of available nitrogen in soil. *Current Science* **25**: 259–260.

Suman J, Dwivedi B S, Dwivedi A K and Pandey S K. 2018. Interaction effect of phosphorus and sulphur on yield and quality of soybean in a vertisol. *International Journal of Current Microbiology and Applied Sciences* **7**(3): 152-158.

Sun T, Wang Y P and Wang Z Y. 2013. The effects of molybdenum and boron on the rhizosphere microorganisms and soil enzyme activities of soybean. *Acta Physiol Plant* **35**: 763-770.

Timotiwu P B, Agustiansyah, Pramono E and Agustin S. 2018. Phosphorus and boron application on growth, yield, quality of soybean seeds (*Glycine max* L. Merril). *Journal of Agricultural Science* **10**(6): 372-382.

Uddin F M J, Mira H H, Sarker U K and Akondo M R I. 2020.Effect of variety and boron fertilizer on the growth and yield performance of French bean (Phaseolus vulgaris L.). *Archives of Agriculture and Environmental Science* **5**(3): 241-246.

USDA. 2020. Soybean area, yield and production. *World Agricultural Production* pp 26.

Vance C P. 1997. Biological fixation of N_2 for ecology and sustainable agriculture. *Springer Verlag* pp 179.

Vance E D, Brookes P C and Jenkinson D S. 1987. An extraction method for measuring soil microbial biomass C. *Soil Biology and Biochemistry* **19**: 703-707.

Verma S N, Sharma M and Urmila. 2018. Effect of INM on soil microbial biomass carbon and enzyme activity under soybean of a typic haplustepts. *International Journal of Current Microbiology and Applied Sciences* **7**(1): 1312-1318.

Vitso, V. 2014. Study on growth and yield of soybean (*Glycine max* L. Merril) cultivars under rainfed condition of Nagaland. M. Sc. (Ag) Thesis, Nagaland University, School of Agricultural Sciences and Rural Development, Medziphema Campus, India.

Walkey, A and Black I A. 1934. An examination of the Degtjareff methiod for determining spil organic carbon matter and a purposed modification of chromic acid titration method. *Soil Science* **37**: 29-38.

Wani M A, Refique M M and Talib A R. 2000. Effect of different levels of sulphur on quality of rice. *Advances in Plant Sciences* **13**(1): 55-57.

Whighum D K. 1983. Potential productivity of field crops under different environments. IRRI, Laos, Banas, Phillipines. pp 205-225.

Yadav H, Shekh M A, Takar S S and Kherawat B S. 2013. Effect of phosphorus and sulphur on growth and yield of summer soybean. *International Journal of Agricultural Sciences* **9**(1): 168-171.

Yadav S N, Singh S K and Kumar O. 2016. Effect of boron on yield attributes, seed yield and oil content of mustard (*Brassica juncea* L.) *Journal of the Indian Society of Soil Science* **64**(3): 291-296.

Yang Y H, Gu H J and Abdullahi B A. 2004. Effect of boron on aluminium toxicity on seedlings of two soybean cultivars. *Water, Air and Soil Pollution* **154**: 239-248.

APPENDIX-I

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on plant height at 30 DAS (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	13.72	13.72	8.24	5.32
Replication	2.00	1.04	0.52	0.59	6.71	3.35	1.37	4.00	13.72	13.72	8.24	5.32
Factor S	2.00	267.09	133.54	152.01*	282.55	141.28	57.64*	4.00	7.75	1.94	1.16*	3.84
Error I	4.00	3.51	0.88	-	9.80	2.45	-	8.00	549.64	137.41	82.54*	3.84
Factor B	2.00	147.58	73.79	58.09*	98.37	49.18	13.37*	4.00	13.32	1.66	-	-
S x B interaction	4.00	224.01	56.00	44.08*	114.38	28.60	7.77*	8.00	245.95	61.49	24.85*	2.78
Error II	12.00	15.24	1.27	-	44.14	3.68	-	24.00	338.40	42.30	17.09	2.36
Factor P	1.00	60.17	60.17	48.78*	42.84	42.84	21.08*	2.00	59.39	2.47	-	-
S x P interaction	2.00	26.09	13.05	10.58*	66.03	33.01	16.24*	4.00	103.01	51.51	31.54*	3.26
B x P interaction	2.00	2.17	1.09	0.88	3.55	1.77	0.87	4.00	92.12	23.03	14.10	2.63
SxBxP interaction	4.00	14.91	3.73	3.02*	26.88	6.72	3.31*	8.00	5.72	1.43	0.88*	2.63
Error III	18.00	22.20	1.23	-	36.59	2.03	-	36.000	41.78	5.22	3.20	2.21
Total	53	784.02	53	-	731.85	-	-	**107**	1529.59	-	-	-

*Significant at 5% level

APPENDIX-II

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on plant height at 60 DAS (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	41.19	41.19	37.91*	5.32
Replication	2.00	19.36	9.68	7.40*	4.65	2.32	2.69	4.00	24.01	6.00	5.52*	3.84
Factor S	2.00	1256.87	628.44	480.27*	1074.63	537.31	621.44*	4.00	2331.50	582.87	536.43*	3.84
Error I	4.00	5.23	1.31	-	3.46	0.86	-	8.00	8.69	1.09	-	-
Factor B	2.00	222.29	111.15	63.54*	186.27	93.13	22.47*	4.00	408.56	102.14	34.66*	2.78
S x B interaction	4.00	168.50	42.13	24.08*	141.07	35.27	8.51*	8.00	309.57	38.70	13.13*	2.36
Error II	12.00	20.99	1.75	-	49.73	4.14	-	24.00	70.72	2.95	-	-
Factor P	1.00	175.68	175.68	82.96*	208.47	208.47	60.98*	2.00	384.15	192.07	69.39*	3.26
S x P interaction	2.00	29.94	14.97	7.07*	39.06	19.53	5.71*	4.00	69.00	17.25	6.23*	2.63
B x P interaction	2.00	0.38	0.19	0.09	1.12	0.56	0.16	4.00	1.51	0.38	0.14	2.63
SxBxP interaction	4.00	73.26	18.31	8.65*	46.99	11.75	3.44*	8.00	120.25	15.03	5.43*	2.21
Error III	18.00	38.12	2.12	-	61.53	3.42	-	36.000	99.650	2.768	-	-
Total	53	2010.63	-	-	1816.98	-	-	**107**	3868.81	-	-	-

*Significant at 5% level

APPENDIX-III

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on plant height at 90 DAS (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	27.00	27.00	20.29*	5.32
Replication	2.00	11.26	5.63	2.97*	1.81	0.91	1.18	4.00	13.07	3.27	2.46	3.84
Factor S	2.00	612.62	306.31	161.77*	585.15	292.57	380.70*	4.00	1197.77	299.44	224.97*	3.84
Error I	4.00	7.57	1.89	-	3.07	0.77	-	8.00	10.65	1.33	-	-
Factor B	2.00	50.73	25.37	13.53*	30.81	15.41	33.96*	4.00	81.55	20.39	17.51*	2.78
S x B interaction	4.00	46.10	11.53	6.15*	9.74	2.44	5.37*	8.00	55.84	6.98	6.00*	2.36
Error II	12.00	22.50	1.87	-	5.44	0.45	-	24.00	27.94	1.16	-	-
Factor P	1.00	181.50	181.50	93.34*	106.96	106.96	101.33*	2.00	288.46	144.23	96.15*	3.26
S x P interaction	2.00	40.08	20.04	10.31*	43.81	21.91	20.75*	4.00	83.90	20.97	13.98*	2.63
B x P interaction	2.00	28.08	14.04	7.22*	6.37	3.19	3.02	4.00	34.45	8.61	5.74*	2.63
SxBxP interaction	4.00	27.08	6.77	3.48*	46.85	11.71	11.10*	8.00	73.94	9.24	6.16*	2.21
Error III	18.00	35.00	1.94	-	19.00	1.06	-	36.000	54.000	1.500	-	-
Total	53	106.52	-	-	859.04	-	-	**107**	1948.57	-	-	-

*Significant at 5% level

APPENDIX-IV

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on number of leaves at 30 DAS (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	2.34	2.34	2.38	5.318
Replication	2.00	9.73	4.86	4.50	11.44	5.72	6.44	4.00	21.17	5.29	5.37*	3.838
Factor S	2.00	4.67	2.34	2.16	13.00	6.50	7.31*	4.00	17.67	4.42	4.48*	3.838
Error I	4.00	4.33	1.08	-	3.56	0.89	-	8.00	7.88	0.99	-	-
Factor B	2.00	14.16	7.08	9.33*	4.33	2.17	2.11	4.00	18.50	4.62	5.18*	2.776
S x B interaction	4.00	2.90	0.73	0.96	6.33	1.58	1.54	8.00	9.24	1.15	1.29	2.355
Error II	12.00	9.10	0.76	-	12.33	1.03	-	24.00	21.44	0.89	-	-
Factor P	1.00	2.53	2.53	1.69	6.69	6.69	6.69*	2.00	9.22	4.61	3.69*	3.259
S x P interaction	2.00	1.14	0.57	0.38	1.81	0.91	0.91	4.00	2.96	0.74	0.59	2.634
B x P interaction	2.00	2.86	1.43	0.95	2.48	1.24	1.24	4.00	5.34	1.34	1.07	2.634
SxBxP interaction	4.00	2.36	0.59	0.39	1.52	0.38	0.38	8.00	3.88	0.49	0.39	2.209
Error III	18.00	27.00	1.50	-	18.00	1.00	-	36.000	45.003	1.25	-	-
Total	53	80.81			81.50			107	164.65			

*Significant at 5% level

APPENDIX-V

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on number of leaves at 60 DAS
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	--	-	-	-	--		1.00	24.94	24.94	17.38*	5.32
Replication	2.00	0.99	0.49	0.63	1.19	0.59	0.28	4.00	2.18	0.54	0.38	3.84
Factor S	2.00	48.94	24.47	31.42*	67.68	33.84	16.18*	4.00	116.62	29.16	20.32*	3.84
Error I	4.00	3.12	0.78	-	8.36	2.09	-	8.00	11.48	1.43	-	-
Factor B	2.00	24.47	12.23	9.42*	27.01	13.50	5.47*	4.00	51.48	12.87	6.83*	2.78
S x B interaction	4.00	31.80	7.95	6.12*	32.68	8.17	3.31*	8.00	64.47	8.06	4.28*	2.36
Error II	12.00	15.58	1.30	-	29.63	2.47	-	24.00	45.21	1.88	-	-
Factor P	1.00	44.28	44.28	41.56*	65.78	65.78	43.55*	2.00	110.06	55.03	42.73*	3.26
S x P interaction	2.00	1.66	0.83	0.78	0.70	0.35	0.23	4.00	2.36	0.59	0.46	2.63
B x P interaction	2.00	4.97	2.49	2.33	0.23	0.12	0.08	4.00	5.21	1.30	1.01	2.63
SxBxP interaction	4.00	10.09	2.52	2.37	5.18	1.29	0.86	8.00	15.27	1.91	1.48	2.21
Error III	18.00	19.18	1.07	-	27.19	1.51	-	36.000	46.363	1.29	-	-
Total	53	205.08	-	-	265.63	-	-	**107**	495.65	-	-	-

*Significant at 5% level

APPENDIX-VI

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on number of leaves at 90 DAS (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	31.15	31.15	12.19*	5.318
Replication	2.00	8.62	4.31	0.92	1.69	0.85	2.07	4.00	10.31	2.58	1.01	3.838
Factor S	2.00	72.79	36.39	7.74*	49.00	24.50	59.80*	4.00	121.79	30.45	11.92*	3.838
Error I	4.00	18.80	4.70	-	1.64	0.41	-	8.00	20.44	2.55	-	-
Factor B	2.00	34.45	17.23	19.38*	24.11	12.06	9.59*	4.00	58.56	14.64	13.65*	2.776
S x B interaction	4.00	37.46	9.37	10.54*	57.22	14.31	11.38*	8.00	94.69	11.84	11.03*	2.355
Error II	12.00	10.67	0.89	-	15.08	1.26	-	24.00	25.75	1.07	-	-
Factor P	1.00	202.23	202.23	79.56*	194.56	194.56	97.96*	2.00	396.79	198.39	87.63*	3.259
S x P interaction	2.00	11.45	5.73	2.25	4.93	2.46	1.24	4.00	16.38	4.09	1.81	2.634
B x P interaction	2.00	0.45	0.23	0.09	1.37	0.69	0.34	4.00	1.82	0.46	0.20	2.634
SxBxP interaction	4.00	30.24	7.56	2.97*	23.52	5.88	2.96*	8.00	53.76	6.72	2.97*	2.209
Error III	18.00	45.75	2.54	-	35.75	1.99	-	36.000	81.500	2.26	-	-
Total	53	472.91	-	-	408.88	-	-	**107**	912.94	-	-	-

*Significant at 5% level

APPENDIX-VII
Effecct of sulphur, boron and phosphorus solubilising biofertilizer on number of nodules at 30 DAS
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	142.60	142.60	97.23*	5.318
Replication	2.000	6.763	3.38	1.60	3.37	1.69	2.04	4.00	10.13	2.53	1.73	3.838
Factor S	2.000	234.961	117.48	55.70*	313.04	156.52	189.93*	4.00	548.00	137.00	93.41*	3.838
Error I	4.000	8.436	2.11	-	3.30	0.82	-	8.00	11.73	1.47	-	-
Factor B	2.000	211.060	105.53	25.40*	113.81	56.91	51.22*	4.00	324.88	81.22	30.85*	2.776
S x B interaction	4.000	241.512	60.38	14.53*	15.19	3.80	3.42*	8.00	256.70	32.09	12.19*	2.355
Error II	12.000	49.858	4.15	-	13.33	1.11	-	24.00	63.19	2.63	-	-
Factor P	1.000	49.116	49.12	6.02*	232.30	232.30	261.33*	2.00	281.41	140.71	31.10*	3.259
S x P interaction	2.000	71.806	35.90	4.40*	19.70	9.85	11.08*	4.00	91.51	22.88	5.06*	2.634
B x P interaction	2.000	85.640	42.82	5.25*	9.15	4.57	5.15*	4.00	94.79	23.70	5.24*	2.634
SxBxP interaction	4.000	196.623	49.16	6.02*	21.85	5.46	6.15**	8.00	218.47	27.31	6.04*	2.209
Error III	18.000	146.890	8.16	-	16.00	0.89	-	36.000	162.890	4.52	-	-
Total	53	1302.67			761.04			107	2206.30			

*Significant at 5% level

APPENDIX-VIII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on number of nodules at 60 DAS (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	2.68	2.68	8.89*	5.318
Replication	2.00	1.44	0.72	2.00	1.04	0.52	2.15	4.00	2.48	0.62	2.06	3.838
Factor S	2.00	129.78	64.89	179.69*	87.81	43.91	182.38*	4.00	217.59	54.40	180.77*	3.838
Error I	4.00	1.44	0.36	-	0.96	0.24	-	8.00	2.41	0.30	-	-
Factor B	2.00	89.33	44.67	141.88*	20.70	10.35	20.70*	4.00	110.04	27.51	67.52*	2.776
S x B interaction	4.00	38.22	9.56	30.35*	34.96	8.74	17.48*	8.00	73.19	9.15	22.45*	2.355
Error II	12.00	3.78	0.31	-	6.00	0.50	-	24.00	9.78	0.41	-	-
Factor P	1.00	90.74	90.74	272.22*	109.80	109.80	141.17*	2.00	200.54	100.27	180.48*	3.259
S x P interaction	2.00	2.81	1.41	4.22*	1.59	0.80	1.02	4.00	4.41	1.10	1.98	2.634
B x P interaction	2.00	26.81	13.41	40.22*	10.26	5.13	6.60*	4.00	37.07	9.27	16.68*	2.634
SxBxP interaction	4.00	7.63	1.91	5.72*	9.85	2.46	3.17*	8.00	17.48	2.19	3.93*	2.209
Error III	18.00	6.00	0.33	-	14.00	0.78	-	36.000	20.000	0.56	-	-
Total	53	398.00	-	-	296.98	-	-	**107**	697.66	-	-	-

*Significant at 5% level

APPENDIX-IX

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on number of branches at 30 DAS (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.59	0.59	2.78	5.318
Replication	2.00	0.93	0.46	1.32	0.04	0.02	0.25	4.00	0.96	0.24	1.13	3.838
Factor S	2.00	0.26	0.13	0.37	0.48	0.24	3.25	4.00	0.74	0.19	0.87	3.838
Error I	4.00	1.41	0.35	-	0.30	0.07	-	8.00	1.70	0.21	-	-
Factor B	2.00	0.93	0.46	1.85	1.15	0.57	1.88	4.00	2.07	0.52	1.87	2.776
S x B interaction	4.00	2.41	0.60	2.41	0.52	0.13	0.42	8.00	2.93	0.37	1.32	2.355
Error II	12.00	3.00	0.25		3.67	0.31	-	24.00	6.67	0.28	-	-
Factor P	1.00	4.74	4.74	12.80*	1.85	1.85	8.33*	2.00	6.59	3.30	11.13*	3.259
S x P interaction	2.00	0.26	0.13	0.35	0.04	0.02	0.08	4.00	0.30	0.07	0.25	2.634
B x P interaction	2.00	0.26	0.13	0.35	0.04	0.02	0.08	4.00	0.30	0.07	0.25	2.634
SxBxP interaction	4.00	1.07	0.27	0.73	0.07	0.02	0.08	8.00	1.15	0.14	0.48	2.209
Error III	18.00	6.67	0.37		4.00	0.22	-	36.000	10.667	0.30	-	-
Total	53	21.93			12.15			107	34.67			

*Significant at 5% level

APPENDIX-X

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on number of branches at 60 DAS (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.55	0.55	39.26*	5.318
Replication	2.00	0.08	0.04	1.99	0.00	0.00	0.25	4.00	0.09	0.02	1.58	3.838
Factor S	2.00	4.94	2.47	115.99*	5.34	2.67	400.75*	4.00	10.28	2.57	183.88*	3.838
Error I	4.00	0.09	0.02	-	0.03	0.01	-	8.00	0.11	0.01	-	-
Factor B	2.00	1.78	0.89	34.90*	3.01	1.50	903.00*	4.00	4.79	1.20	88.05*	2.776
S x B interaction	4.00	1.00	0.25	9.81*	1.06	0.26	158.50*	8.00	2.06	0.26	18.91*	2.355
Error II	12.00	0.31	0.03	-	0.02	0.00	-	24.00	0.33	0.01	-	-
Factor P	1.00	5.29	5.29	282.78*	3.23	3.23	245.41*	2.00	8.52	4.26	267.35*	3.259
S x P interaction	2.00	0.14	0.07	3.69*	0.64	0.32	24.38*	4.00	0.78	0.19	12.23*	2.634
B x P interaction	2.00	0.51	0.25	13.58*	0.10	0.05	3.85*	4.00	0.61	0.15	9.56*	2.634
SxBxP interaction	4.00	0.62	0.16	8.33*	1.07	0.27	20.43*	8.00	1.70	0.21	13.32*	2.209
Error III	18.00	0.34	0.02	-	0.24	0.01	-	36.000	0.573	0.02	-	-
Total	53	15.10			14.74			**107**	30.39			

*Significant at 5% level

APPENDIX-XI

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on dry matter per plant at 60 DAS (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.000	0.067	0.07	0.24	5.318
Replication	2.000	1.783	0.89	1.94	0.509	0.254	2.40	4.000	2.291	0.57	2.03	3.838
Factor S	2.000	34.791	17.40	37.88*	27.702	13.851	130.90*	4.000	62.493	15.62	55.30*	3.838
Error I	4.000	1.837	0.46	-	0.423	0.106	-	8.000	2.260	0.28	-	-
Factor B	2.000	37.991	19.00	48.73*	19.378	9.689	47.77*	4.000	57.369	14.34	48.40*	2.776
S x B interaction	4.000	6.057	1.51	3.88*	3.349	0.837	4.13*	8.000	9.406	1.18	3.97	2.355
Error II	12.000	4.678	0.39	-	2.434	0.203	-	24.000	7.112	0.30	-	-
Factor P	1.000	8.704	8.70	24.79*	23.115	23.115	242.00*	2.000	31.819	15.91	71.24*	3.259
S x P interaction	2.000	0.505	0.25	0.72	2.491	1.245	13.04*	4.000	2.996	0.75	3.35*	2.634
B x P interaction	2.000	1.274	0.64	1.81	0.236	0.118	1.24	4.000	1.511	0.38	1.69	2.634
SxBxP interaction	4.000	14.676	3.67	10.45*	1.146	0.286	3.00*	8.000	15.822	1.98	8.86*	2.209
Error III	18.000	6.321	0.35	-	1.719	0.096	-	36.000	8.040	0.22	-	-
Total	53	118.62			82.50			107	201.9			

*Significant at 5% level

APPENDIX-XII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on dry matter per plant at 90 DAS (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.16	0.16	5.27	5.32
Replication	2.00	0.00	0.00	0.08	0.17	0.08	1.65	4.00	0.17	0.04	1.37	3.84
Factor S	2.00	93.16	46.58	4187.84*	128.30	64.15	1254.95 *	4.00	221.45	55.36	1779.07*	3.84
Error I	4.00	0.04	0.01	-	0.20	0.05	-	8.00	0.25	0.03	-	-
Factor B	2.00	21.16	10.58	1327.63*	19.58	9.79	131.51*	4.00	40.74	10.19	247.17*	2.78
S x B interaction	4.00	0.28	0.07	8.70*	1.29	0.32	4.32*	8.00	1.56	0.20	4.74*	2.36
Error II	12.00	0.10	0.01	-	0.89	0.07	-	24.00	0.99	0.04	-	-
Factor P	1.00	3.88	3.88	517.50*	2.60	2.60	41.47*	2.00	6.48	3.24	92.21*	3.26
S x P interaction	2.00	0.07	0.03	4.53*	0.74	0.37	5.90*	4.00	0.81	0.20	5.76*	2.63
B x P interaction	2.00	0.45	0.22	29.92*	1.76	0.88	13.99*	4.00	2.21	0.55	15.69*	2.63
SxBxP interaction	4.00	0.09	0.02	2.96*	1.10	0.28	4.39*	8.00	1.19	0.15	4.24*	2.21
Error III	18.00	0.13	0.01	-	1.13	0.06	-	36.00	1.27	0.04	-	-
Total	53	119.35			157.77			107	277.28			

*Significant at 5% level

APPENDIX-XIII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on number of pods per plant
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	6.91	6.91	119.21	5.32*
Replication	2.00	0.02	0.01	0.11	0.02	0.01	0.34	4.00	0.04	0.01	0.18	3.84
Factor S	2.00	3757.35	1878.67	23426.47*	4138.09	2069.05	58007.63*	4.00	7895.44	1973.86	34072.31	3.84*
Error I	4.00	0.32	0.08	-	0.14	0.04	-	8.00	0.46	0.06	-	-
Factor B	2.00	338.16	169.08	4770.11*	416.95	208.48	13740.71*	4.00	755.11	188.78	7458.98	2.78*
S x B interaction	4.00	51.85	12.96	365.67*	15.35	3.84	252.97*	8.00	67.20	8.40	331.89	2.36*
Error II	12.00	0.43	0.04	-	0.18	0.02	-	24.00	0.61	0.03	-	-
Factor P	1.00	17.56	17.56	331.87*	19.15	19.15	4035.37*	2.00	36.71	18.35	636.80	3.26*
S x P interaction	2.00	2.18	1.09	20.64*	0.05	0.02	4.92*	4.00	2.23	0.56	19.35	2.63*
B x P interaction	2.00	0.38	0.19	3.57*	0.22	0.11	22.97*	4.00	0.60	0.15	5.16	2.63*
SxBxP interaction	4.00	2.98	0.75	14.09*	2.43	0.61	128.09*	8.00	5.41	0.68	23.47	2.21*
Error III	18.00	0.95	0.05	-	0.09	0.00	-	36.00	1.04	0.03	-	-
Total	53	4172.16			4592.68			107	8771.75			

*Significant at 5% level

APPENDIX-XIV

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on number of filled pods per plant
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	55.58	55.58	397.39*	5.32
Replication	2.00	0.11	0.06	0.55	0.43	0.22	1.21	4.00	0.54	0.14	0.97	3.84
Factor S	2.00	3957.11	1978.56	19646.95*	4901.74	2450.87	13688.48*	4.00	8858.86	2214.71	15833.42*	3.84
Error I	4.00	0.40	0.10		0.72	0.18	-	8.00	1.12	0.14	-	-
Factor B	2.00	564.07	282.03	4526.41*	536.31	268.16	550.10*	4.00	1100.38	275.09	1000.75*	2.78
S x B interaction	4.00	28.77	7.19	115.42*	28.12	7.03	14.42*	8.00	56.89	7.11	25.87*	2.36
Error II	12.00	0.75	0.06	-	5.85	0.49	-	24.00	6.60	0.27	-	-
Factor P	1.00	30.38	30.38	411.52*	55.45	55.45	162.90*	2.00	85.82	42.91	207.20*	3.26
S x P interaction	2.00	0.58	0.29	3.93*	6.21	3.10	9.12*	4.00	6.79	1.70	8.19*	2.63
B x P interaction	2.00	0.53	0.26	3.57*	2.49	1.24	3.65*	4.00	3.01	0.75	3.64*	2.63
SxBxP interaction	4.00	1.48	0.37	5.00*	7.38	1.85	5.42*	8.00	8.86	1.11	5.35*	2.21
Error III	18.00	1.33	0.07	-	6.13	0.34	-	36.00	7.46	0.21	-	-
Total	53	4585.49			5550.84			107	10191.92			

*Significant at 5% level

APPENDIX-XV

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on number of seeds per pod
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	--	-	-	1.00	0.00	0.00	0.98	5.32
Replication	2.00	0.01	0.00	0.69	0.01	0.01	2.94	4.00	0.02	0.00	1.46	3.84
Factor S	2.00	0.22	0.11	26.04*	0.26	0.13	58.58*	4.00	0.47	0.12	37.21*	3.84
Error I	4.00	0.02	0.00	-	0.01	0.00	-	8.00	0.03	0.00	-	-
Factor B	2.00	0.07	0.03	4.21*	0.04	0.02	4.71*	4.00	0.11	0.03	4.39*	2.78
S x B interaction	4.00	0.02	0.01	0.77	0.03	0.01	1.79	8.00	0.06	0.01	1.14	2.36
Error II	12.00	0.10	0.01	-	0.05	0.00	-	24.00	0.15	0.01	-	-
Factor P	1.00	0.01	0.01	1.53	0.01	0.01	2.22	2.00	0.02	0.01	1.82	3.26
S x P interaction	2.00	0.00	0.00	0.22	0.00	0.00	0.28	4.00	0.01	0.00	0.25	2.63
B x P interaction	2.00	0.00	0.00	0.31	0.00	0.00	0.30	4.00	0.01	0.00	0.31	2.63
SxBxP interaction	4.00	0.01	0.00	0.18	0.00	0.00	0.20	8.00	0.01	0.00	0.19	2.21
Error III	18.00	0.13	0.01	-	0.09	0.01	-	36.00	0.22	0.01	-	-
Total	53	0.58			0.52			**107**	1.10			

*Significant at 5% level

APPENDIX-XVI

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on seed test weight
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	1.39	1.39	18.13*	5.32
Replication	2.00	0.02	0.01	0.09	0.10	0.05	1.56	4.00	0.12	0.03	0.41	3.84
Factor S	2.00	19.61	9.81	81.45*	25.92	12.96	397.48*	4.00	45.53	11.38	148.80*	3.84
Error I	4.00	0.48	0.12	-	0.13	0.03	-	8.00	0.61	0.08	-	-
Factor B	2.00	2.87	1.43	42.01*	5.12	2.56	35.62*	4.00	7.98	2.00	37.68*	2.78
S x B interaction	4.00	0.67	0.17	4.92*	1.37	0.34	4.76*	8.00	2.04	0.25	4.81*	2.36
Error II	12.00	0.41	0.03	-	0.86	0.07	-	24.00	1.27	0.05	-	-
Factor P	1.00	0.46	0.46	6.43*	0.41	0.41	7.41*	2.00	0.87	0.44	6.86*	3.26
S x P interaction	2.00	0.01	0.01	0.09	0.12	0.06	1.05	4.00	0.13	0.03	0.51	2.63
B x P interaction	2.00	0.23	0.12	1.63	0.34	0.17	3.03	4.00	0.57	0.14	2.24	2.63
SxBxP interaction	4.00	0.06	0.01	0.21	0.36	0.09	1.62	8.00	0.42	0.05	0.82	2.21
Error III	18.00	1.29	0.07	-	1.00	0.06	-	36.00	2.29	0.06	-	-
Total	53	26.12			35.75							

*Significant at 5% level

APPENDIX-XVII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on harvest index (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	5.04	5.04	52.80*	5.32
Replication	2.00	0.08	0.04	0.26	0.31	0.16	4.48	4.00	0.39	0.10	1.03	3.84
Factor S	2.00	50.69	25.34	162.53*	63.29	31.65	909.54*	4.00	113.98	28.50	298.81*	3.84
Error I	4.00	0.62	0.16	-	0.14	0.03	-	8.00	0.76	0.10	-	-
Factor B	2.00	8.64	4.32	53.91*	10.98	5.49	86.01*	4.00	19.62	4.90	68.14*	2.78
S x B interaction	4.00	3.47	0.87	10.83*	0.92	0.23	3.60*	8.00	4.39	0.55	7.63*	2.36
Error II	12.00	0.96	0.08		0.77	0.06	-	24.00	1.73	0.07	-	-
Factor P	1.00	0.26	0.26	1.83	0.28	0.28	2.96	2.00	0.54	0.27	2.29	3.26
S x P interaction	2.00	0.62	0.31	2.21	0.37	0.18	1.94	4.00	0.99	0.25	2.10	2.63
B x P interaction	2.00	0.20	0.10	0.71	0.48	0.24	2.54	4.00	0.68	0.17	1.45	2.63
SxBxP interaction	4.00	0.47	0.12	0.83	1.08	0.27	2.85	8.00	1.55	0.19	1.65	2.21
Error III	18.00	2.52	0.14		1.71	0.09	-	36.00	4.22	0.12	-	-
Total	53	68.52			80.33			**107**	153.88			

*Significant at 5% level

APPENDIX-XVIII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on N uptake by stover (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	46.58	46.58	90.44	5.32*
Replication	2.00	1.59	0.80	2.31	0.07	0.03	0.05	4.00	1.66	0.41	0.80	3.84
Factor S	2.00	2839.16	1419.58	4128.86*	2862.83	1431.42	2085.67*	4.00	5701.99	1425.50	2767.61	3.84*
Error I	4.00	1.38	0.34	-	2.75	0.69	-	8.00	4.12	0.52	-	-
Factor B	2.00	306.03	153.01	400.11*	271.76	135.88	480.10*	4.00	577.79	144.45	434.13	2.78*
S x B interaction	4.00	118.11	29.53	77.21*	98.15	24.54	86.70*	8.00	216.26	27.03	81.25	2.36*
Error II	12.00	4.59	0.38	-	3.40	0.28	-	24.00	7.99	0.33	-	-
Factor P	1.00	38.35	38.35	111.65*	41.05	41.05	180.88*	2.00	79.40	39.70	139.19	3.26*
S x P interaction	2.00	9.48	4.74	13.80*	7.00	3.50	15.42*	4.00	16.48	4.12	14.44	2.63*
B x P interaction	2.00	3.97	1.99	5.79*	1.64	0.82	3.62*	4.00	5.62	1.40	4.92	2.63*
SxBxP interaction	4.00	7.72	1.93	5.62*	12.03	3.01	13.25*	8.00	19.75	2.47	8.66	2.21*
Error III	18.00	6.18	0.34	-	4.08	0.23	-	36.00	10.27	0.29	-	-
Total	53	3336.58	-	-	3304.74	-	-	107	6687.90	-	-	-

*Significant at 5% level

APPENDIX-XIX

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on P uptake by stover
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	**SS**	**MSS**	**Fcal**	**SS**	**MSS**	**F cal**	**DF**	**SS**	**MSS**	**Fcal**	
Year	-	-	-	-	-	-	-	1.00	0.11	0.11	2.66	5.32
Replication	2.00	0.32	0.16	2.74	0.02	0.01	0.31	4.00	0.34	0.08	2.03	3.84
Factor S	2.00	93.17	46.58	792.6*4	86.68	43.34	1788.07*	4.00	179.85	44.96	1083.31*	3.84
Error I	4.00	0.24	0.06		0.10	0.02		8.00	0.33	0.04		
Factor B	2.00	14.26	7.13	100.12*	10.48	5.24	315.41*	4.00	24.75	6.19	140.85*	2.78
S x B interaction	4.00	1.30	0.33	4.57*	0.57	0.14	8.61*	8.00	1.87	0.23	5.34*	2.36
Error II	12.00	0.85	0.07		0.20	0.02		24.00	1.05	0.04		
Factor P	1.00	6.82	6.82	109.18*	6.74	6.74	764.96*	2.00	13.56	6.78	190.26*	3.26
S x P interaction	2.00	1.12	0.56	8.99*	0.07	0.04	4.19*	4.00	1.20	0.30	8.40*	2.63
B x P interaction	2.00	1.04	0.52	8.36*	0.13	0.07	7.47*	4.00	1.18	0.29	8.25*	2.63
SxBxP interaction	4.00	0.83	0.21	3.30*	0.25	0.06	7.18*	8.00	1.08	0.13	3.78*	2.21
Error III	18.00	1.12	0.06		0.16	0.01		36.00	1.28	0.04		
Total	53	121.08	-	-	105.41	-	-	**107**	226.60	-	-	-

*Significant at 5% level

APPENDIX-XX

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on K uptake by stover
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.88	0.88	1.76	5.32
Replication	2.00	0.30	0.15	0.22	0.18	0.09	0.30	4.00	0.49	0.12	0.24	3.84
Factor S	2.00	2201.32	1100.66	1568.55*	2154.45	1077.23	3543.62*	4.00	4355.78	1088.94	2165.55*	3.84
Error I	4.00	2.81	0.70	-	1.22	0.30	-	8.00	4.02	0.50	-	-
Factor B	2.00	203.61	101.81	392.51*	212.53	106.27	1372.82*	4.00	416.15	104.04	617.83*	2.78
S x B interaction	4.00	11.47	2.87	11.06*	10.81	2.70	34.92*	8.00	22.28	2.79	16.54*	2.36
Error II	12.00	3.11	0.26	-	0.93	0.08	-	24.00	4.04	0.17	-	-
Factor P	1.00	22.98	22.98	290.07*	17.41	17.41	200.62*	2.00	40.39	20.20	243.32*	3.26
S x P interaction	2.00	1.27	0.64	8.03*	1.22	0.61	7.01*	4.00	2.49	0.62	7.50*	2.63
B x P interaction	2.00	0.71	0.35	4.45*	0.64	0.32	3.70*	4.00	1.35	0.34	4.06*	2.63
SxBxP interaction	4.00	2.27	0.57	7.18*	5.46	1.36	15.72*	8.00	7.73	0.97	11.64*	2.21
Error III	18.00	1.43	0.08	-	1.56	0.09	-	36.00	2.99	0.08	-	-
Total	53	2451.29			2406.41			**107**	4858.59			

*Significant at 5% level

APPENDIX-XX1

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on K uptake by stover
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.88	0.88	1.76	5.32
Replication	2.00	0.30	0.15	0.22	0.18	0.09	0.30	4.00	0.49	0.12	0.24	3.84
Factor S	2.00	2201.32	1100.66	1568.55*	2154.45	1077.23	3543.62*	4.00	4355.78	1088.94	2165.55*	3.84
Error I	4.00	2.81	0.70	-	1.22	0.30	-	8.00	4.02	0.50	-	-
Factor B	2.00	203.61	101.81	392.51*	212.53	106.27	1372.82*	4.00	416.15	104.04	617.83*	2.78
S x B interaction	4.00	11.47	2.87	11.06*	10.81	2.70	34.92*	8.00	22.28	2.79	16.54*	2.36
Error II	12.00	3.11	0.26	-	0.93	0.08	-	24.00	4.04	0.17	-	-
Factor P	1.00	22.98	22.98	290.07*	17.41	17.41	200.62*	2.00	40.39	20.20	243.32*	3.26
S x P interaction	2.00	1.27	0.64	8.03*	1.22	0.61	7.01*	4.00	2.49	0.62	7.50*	2.63
B x P interaction	2.00	0.71	0.35	4.45*	0.64	0.32	3.70*	4.00	1.35	0.34	4.06*	2.63
SxBxP interaction	4.00	2.27	0.57	7.18*	5.46	1.36	15.72*	8.00	7.73	0.97	11.64*	2.21
Error III	18.00	1.43	0.08	-	1.56	0.09	-	36.00	2.99	0.08	-	-
Total	53	2451.29			2406.41			**107**	4858.59			

*Significant at 5% level

APPENDIX-XX1I

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on S uptake by stover (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.00	0.00	0.81	5.32
Replication	2.00	0.01	0.01	0.97	0.06	0.03	16.53*	4.00	0.07	0.02	4.97*	3.84
Factor S	2.00	47.55	23.78	4602.88*	55.50	27.75	15520.26*	4.00	103.05	25.76	7410.00*	3.84
Error I	4.00	0.02	0.01	-	0.01	0.00	-	8.00	0.03	0.00	-	-
Factor B	2.00	6.55	3.27	1328.10*	7.37	3.69	563.74*	4.00	13.92	3.48	773.01*	2.78
S x B interaction	4.00	1.79	0.45	181.68*	1.20	0.30	45.93*	8.00	2.99	0.37	83.10*	2.36
Error II	12.00	0.03	0.00	-	0.08	0.01	-	24.00	0.11	0.00	-	-
Factor P	1.00	0.72	0.72	230.48*	0.90	0.90	236.07*	2.00	1.62	0.81	233.55*	3.26
S x P interaction	2.00	0.12	0.06	18.91*	0.15	0.07	19.18*	4.00	0.26	0.07	19.05*	2.63
B x P interaction	2.00	0.03	0.01	4.69*	0.03	0.02	4.46*	4.00	0.06	0.02	4.57*	2.63
SxBxP interaction	4.00	0.13	0.03	10.11*	0.14	0.04	9.37*	8.00	0.27	0.03	9.70*	2.21
Error III	18.00	0.06	0.00	-	0.07	0.00	-	36.00	0.12	0.00	-	-
Total	53	57.00	-	-	65.50	-	-	**107**	122.51	-	-	-

*Significant at 5% level

APPENDIX-XX1II

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on B uptake by stover (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.04	0.04	0.77	5.32
Replication	2.00	0.10	0.05	1.54	0.14	0.07	1.04	4.00	0.24	0.06	1.20	3.84
Factor S	2.00	8621.24	4310.62	136507.98*	9063.81	4531.9 1	65525.03*	4.00	17685.05	4421.26	87775.05*	3.84
Error I	4.00	0.13	0.03	-	0.28	0.07	-	8.00	0.40	0.05	-	-
Factor B	2.00	954.97	477.48	7202.99*	1035.94	517.97	6376.45*	4.00	1990.91	497.73	6747.86*	2.78
S x B interaction	4.00	77.56	19.39	292.50*	77.79	19.45	239.41*	8.00	155.35	19.42	263.27*	2.36
Error II	12.00	0.80	0.07	-	0.97	0.08	-	24.00	1.77	0.07	-	-
Factor P	1.00	90.64	90.64	680.86*	81.97	81.97	1120.43*	2.00	172.60	86.30	836.75*	3.26
S x P interaction	2.00	3.61	1.80	13.54*	3.47	1.74	23.74*	4.00	7.08	1.77	17.16*	2.63
B x P interaction	2.00	3.64	1.82	13.67*	0.77	0.38	5.24*	4.00	4.40	1.10	10.68*	2.63
SxBxP interaction	4.00	1.59	0.40	2.99*	5.75	1.44	19.66*	8.00	7.34	0.92	8.90*	2.21
Error III	18.00	2.40	0.13	-	1.32	0.07	-	36.00	3.71	0.10	-	-
Total	53	9756.65			10272.21			**107**	20028.90			

*Significant at 5% level

APPENDIX-XX1V

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on N uptake by seeds
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	17.80	17.80	52.54*	5.32
Replication	2.00	4.83	2.41	9.66*	6.14	3.07	7.18	4.00	10.96	2.74	8.09*	3.84
Factor S	2.00	11286.74	5643.37	22582.84*	12113.61	6056.8 1	14166.95*	4.00	23400.35	5850.09	17271.49*	3.84
Error I	4.00	1.00	0.25	-	1.71	0.43	-	8.00	2.71	0.34	-	-
Factor B	2.00	1674.83	837.41	2276.08*	1368.73	684.37	1026.32*	4.00	3043.56	760.89	1470.70*	2.78
S x B interaction	4.00	260.52	65.13	177.02*	121.48	30.37	45.55*	8.00	382.00	47.75	92.29*	2.36
Error II	12.00	4.42	0.37	-	8.00	0.67	-	24.00	12.42	0.52	-	-
Factor P	1.00	102.95	102.95	186.19*	167.20	167.20	110.86*	2.00	270.15	135.07	131.07*	3.26
S x P interaction	2.00	22.82	11.41	20.63*	35.30	17.65	11.70*	4.00	58.12	14.53	14.10*	2.63
B x P interaction	2.00	11.89	5.95	10.75*	20.30	10.15	6.73*	4.00	32.19	8.05	7.81*	2.63
SxBxP interaction	4.00	7.07	1.77	3.20*	21.34	5.33	3.54*	8.00	28.41	3.55	3.45*	2.21
Error III	18.00	9.95	0.55	-	27.15	1.51	-	36.00	37.10	1.03	-	-
Total	53	13387.01	-	-	-	-	-	107	27295.76	-	-	-

*Significant at 5% level

APPENDIX-XXV

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on P uptake by seeds (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.00	0.00	0.16	5.32
Replication	2.00	0.00	0.00	0.43	0.00	0.00	0.36	4.00	0.01	0.00	0.41	3.84
Factor S	2.00	84.81	42.41	9125.20*	83.11	41.56	29526.64*	4.00	167.93	41.98	13867.55*	3.84
Error I	4.00	0.02	0.00	-	0.01	0.00	-	8.00	0.02	0.00	-	-
Factor B	2.00	8.36	4.18	1358.41*	7.62	3.81	5884.84*	4.00	15.98	3.99	2144.88*	2.78
S x B interaction	4.00	0.06	0.01	4.67*	0.06	0.01	21.37*	8.00	0.11	0.01	7.57*	2.36
Error II	12.00	0.04	0.00	-	0.01	0.00	-	24.00	0.04	0.00	-	-
Factor P	1.00	1.04	1.04	308.58*	1.01	1.01	872.83*	2.00	2.05	1.02	452.76*	3.26
S x P interaction	2.00	0.04	0.02	6.64*	0.05	0.02	20.28*	4.00	0.09	0.02	10.13*	2.63
B x P interaction	2.00	0.04	0.02	5.96*	0.01	0.00	4.25*	4.00	0.05	0.01	5.52*	2.63
SxBxP interaction	4.00	0.05	0.01	3.51*	0.06	0.01	12.77*	8.00	0.11	0.01	5.88*	2.21
Error III	18.00	0.06	0.00	-	0.02	0.00	-	36.00	0.08	0.00	-	-
Total	53	94.52	-	-	53	94.52	-	**107**	186.47	-	-	-

*Significant at 5% level

APPENDIX-XXVI

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on K uptake by seeds
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.02	0.02	3.56	5.32
Replication	2.00	0.07	0.04	4.92	0.01	0.00	0.86	4.00	0.08	0.02	3.19	3.84
Factor S	2.00	242.61	121.31	16721.25*	241.65	120.82	22344.19*	4.00	484.26	121.07	19122.56*	3.84
Error I	4.00	0.03	0.01	-	0.02	0.01	-	8.00	0.05	0.01	-	-
Factor B	2.00	33.43	16.71	1259.68*	36.69	18.35	3728.77*	4.00	70.12	17.53	1927.61*	2.78
S x B interaction	4.00	4.44	1.11	83.65*	2.87	0.72	145.68*	8.00	7.31	0.91	100.43*	2.36
Error II	12.00	0.16	0.01	-	0.06	0.00	-	24.00	0.22	0.01	-	-
Factor P	1.00	6.07	6.07	325.66*	4.57	4.57	688.05*	2.00	10.64	5.32	420.83*	3.26
S x P interaction	2.00	0.77	0.38	20.56*	0.19	0.09	14.25*	4.00	0.96	0.24	18.90*	2.63
B x P interaction	2.00	0.22	0.11	5.77*	0.07	0.04	5.61*	4.00	0.29	0.07	5.73*	2.63
SxBxP interaction	4.00	0.31	0.08	4.20*	0.46	0.12	17.41*	8.00	0.78	0.10	7.67*	2.21
Error III	18.00	0.34	0.02	-	0.12	0.01	-	36.00	0.46	0.01	-	-
Total	53	288.45	-	-	286.72	-	-	**107**	575.18	-	-	-

*Significant at 5% level

APPENDIX-XXVII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on S uptake by seeds
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.02	0.02	8.40*	5.32
Replication	2.00	0.00	0.00	0.33	0.00	0.00	0.54	4.00	0.01	0.00	0.46	3.84
Factor S	2.00	74.42	37.21	18028.97	77.78	38.89	11311.24*	4.00	152.19	38.05	13831.24*	3.84
Error I	4.00	0.01	0.00	-	0.01	0.00	-	8.00	0.02	0.00	-	-
Factor B	2.00	7.21	3.60	1746.57	7.91	3.95	533.05*	4.00	15.12	3.78	797.18*	2.78
S x B interaction	4.00	0.53	0.13	63.86	0.65	0.16	21.82*	8.00	1.17	0.15	30.97*	2.36
Error II	12.00	0.02	0.00	-	0.09	0.01	-	24.00	0.11	0.00	-	-
Factor P	1.00	0.70	0.70	330.99	0.92	0.92	435.51*	2.00	1.62	0.81	383.23*	3.26
S x P interaction	2.00	0.00	0.00	0.11	0.06	0.03	14.12*	4.00	0.06	0.01	7.11*	2.63
B x P interaction	2.00	0.07	0.03	15.73	0.06	0.03	14.25*	4.00	0.13	0.03	14.99*	2.63
SxBxP interaction	4.00	0.08	0.02	8.98	0.06	0.01	6.56*	8.00	0.13	0.02	7.77*	2.21
Error III	18.00	0.04	0.00	-	0.04	0.00	-	36.00	0.08	0.00	-	-
Total	53	83.07	-	-	87.57		-	**107**	170.66		-	-

*Significant at 5% level

APPENDIX-XXVIII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on B uptake by seeds
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	7.46	7.46	18.65*	5.32
Replication	2.00	4.56	2.28	3.67	0.29	0.15	0.83	4.00	4.86	1.21	3.04	3.84
Factor S	2.00	9731.37	4865.69	7825.53*	9880.98	4940.49	27770.43*	4.00	19612.35	4903.09	12262.69*	3.84
Error I	4.00	2.49	0.62	-	0.71	0.18	-	8.00	3.20	0.40	-	-
Factor B	2.00	2015.29	1007.65	3218.02*	2137.08	1068.54	7165.53*	4.00	4152.37	1038.09	4491.49*	2.78
S x B interaction	4.00	258.74	64.68	206.58*	156.68	39.17	262.68*	8.00	415.42	51.93	224.68*	2.36
Error II	12.00	3.76	0.31	-	1.79	0.15	-	24.00	5.55	0.23	-	-
Factor P	1.00	92.93	92.93	175.89*	48.39	48.39	248.02*	2.00	141.33	70.66	195.34*	3.26
S x P interaction	2.00	19.01	9.51	17.99*	9.42	4.71	24.14*	4.00	28.43	7.11	19.65*	2.63
B x P interaction	2.00	8.65	4.32	8.18*	2.93	1.46	7.50*	4.00	11.58	2.89	8.00*	2.63
SxBxP interaction	4.00	7.21	1.80	3.41*	2.70	0.67	3.46*	8.00	9.91	1.24	3.42*	2.21
Error III	18.00	9.51	0.53	-	3.51	0.20	-	36.00	13.02	0.36	-	-
Total	53	12153.52	-	-	12244.49	-	-	**107**	24405.47	-	-	-

*Significant at 5% level

APPENDIX-XXIX

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on total N uptake
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	121.96	121.96	91.46*	5.32
Replication	2.00	8.43	4.21	4.51	5.47	2.73	1.58	4.00	13.90	3.47	2.61	3.84
Factor S	2.00	-	12692.64	13595.38*	26692.07	13346.04	7699.26*	4.00	52077.34	13019.34	9763.22*	3.84
Error I	4.00	3.73	0.93	-	6.93	1.73	-	8.00	10.67	1.33	-	-
Factor B	2.00	3412.18	1706.09	3045.13*	2856.58	1428.29	1233.49*	4.00	6268.76	1567.19	1824.23*	2.78
S x B interaction	4.00	720.80	180.20	321.63*	391.42	97.86	84.51*	8.00	1112.22	139.03	161.83*	2.36
Error II	12.00	6.72	0.56	-	13.90	1.16	-	24.00	20.62	0.86	-	-
Factor P	1.00	266.98	266.98	341.04*	373.93	373.93	200.49*	2.00	640.91	320.46	242.04*	3.26
S x P interaction	2.00	60.69	30.35	38.77*	69.88	34.94	18.73*	4.00	130.58	32.64	24.66*	2.63
B x P interaction	2.00	26.96	13.48	17.22*	33.42	16.71	8.96*	4.00	60.38	15.10	11.40*	2.63
SxBxP interaction	4.00	13.18	3.30	4.21*	39.01	9.75	5.23*	8.00	52.20	6.52	4.93*	2.21
Error III	18.00	14.09	0.78	-	33.57	1.87	-	36.00	47.66	1.32	-	-
Total	53	29919.05	-	-	30516.19	-	-	107	-	-	-	-

*Significant at 5% level

APPENDIX-XXX

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on total P uptake

(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.13	0.13	2.74	5.32
Replication	2.00	0.34	0.17	2.29	0.02	0.01	0.71	4.00	0.37	0.09	2.00	3.84
Factor S	2.00	355.61	177.80	2377.40*	337.23	168.61	10015.54*	4.00	692.83	173.21	3780.84*	3.84
Error I	4.00	0.30	0.07	-	0.07	0.02	-	8.00	0.37	0.05	-	-
Factor B	2.00	43.90	21.95	261.11*	35.95	17.97	1026.31*	4.00	79.85	19.96	393.04*	2.78
S x B interaction	4.00	1.09	0.27	3.23	0.70	0.18	10.00*	8.00	1.79	0.22	4.40*	2.36
Error II	12.00	1.01	0.08	-	0.21	0.02	-	24.00	1.22	0.05	-	-
Factor P	1.00	13.18	13.18	185.60*	12.97	12.97	1103.26*	2.00	26.15	13.07	315.89*	3.26
S x P interaction	2.00	0.72	0.36	5.09*	0.00	0.00	0.13	4.00	0.73	0.18	4.39*	2.63
B x P interaction	2.00	1.29	0.64	9.06*	0.13	0.06	5.35*	4.00	1.41	0.35	8.53*	2.63
SxBxP interaction	4.00	1.10	0.28	3.89*	0.40	0.10	8.44*	8.00	1.50	0.19	4.53*	2.21
Error III	18.00	1.28	0.07	-	0.21	0.01	-	36.00	1.49	0.04	-	-
Total	53	419.82	-	-	387.88	-	-	**107**	807.83	-	-	-

*Significant at 5% level

APPENDIX-XXXI

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on total K uptake (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	1.19	1.19	2.30	5.32
Replication	2.00	0.12	0.06	0.08	0.11	0.06	0.21	4.00	0.23	0.06	0.11	3.84
Factor S	2.00	3901.35	1950.67	2560.59*	3839.12	1919.56	7121.60*	4.00	7740.47	1935.12	3752.60*	3.84
Error I	4.00	3.05	0.76	-	1.08	0.27	-	8.00	4.13	0.52	-	-
Factor B	2.00	402.04	201.02	751.70*	425.26	212.63	2524.64*	4.00	827.30	206.82	1176.34*	2.78
S x B interaction	4.00	16.99	4.25	15.88*	12.83	3.21	38.08*	8.00	29.82	3.73	21.20*	2.36
Error II	12.00	3.21	0.27	-	1.01	0.08	-	24.00	4.22	0.18	-	-
Factor P	1.00	52.69	52.69	710.06*	39.82	39.82	485.54*	2.00	92.51	46.25	592.19*	3.26
S x P interaction	2.00	3.11	1.56	20.97*	0.51	0.25	3.09	4.00	3.62	0.90	11.59*	2.63
B x P interaction	2.00	1.66	0.83	11.16*	0.49	0.25	2.99	4.00	2.15	0.54	6.87*	2.63
SxBxP interaction	4.00	3.01	0.75	10.15*	6.68	1.67	20.36*	8.00	9.69	1.21	15.51*	2.21
Error III	18.00	1.34	0.07	-	1.48	0.08	-	36.00	2.81	0.08	-	-
Total	53	4388.55	-	-	4328.38	-	-	**107**	8718.12	-	-	-

*Significant at 5% level

APPENDIX-XXXII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on total S uptake (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	--	-	-	-	-	1.00	0.01	0.01	4.36	5.32
Replication	2.00	0.02	0.01	4.14	0.08	0.04	16.70*	4.00	0.10	0.02	10.77*	3.84
Factor S	2.00	239.92	119.96	56477.45*	264.58	132.29	55636.49*	4.00	504.51	126.13	56033.27*	3.84
Error I	4.00	0.01	0.00	-	0.01	0.00	-	8.00	0.02	0.00	-	-
Factor B	2.00	27.40	13.70	3208.45*	30.53	15.26	3076.06*	4.00	57.92	14.48	3137.29*	2.78
S x B interaction	4.00	3.46	0.86	202.54*	3.16	0.79	159.02*	8.00	6.62	0.83	179.15*	2.36
Error II	12.00	0.05	0.00	-	0.06	0.00	-	24.00	0.11	0.00	-	-
Factor P	1.00	2.83	2.83	436.94*	3.63	3.63	440.85*	2.00	6.46	3.23	439.13*	3.26
S x P interaction	2.00	0.11	0.05	8.24*	0.39	0.19	23.62*	4.00	0.50	0.12	16.85*	2.63
B x P interaction	2.00	0.02	0.01	1.53	0.04	0.02	2.44	4.00	0.06	0.02	2.04	2.63
SxBxP interaction	4.00	0.15	0.04	5.79*	0.19	0.05	5.78*	8.00	0.34	0.04	5.79*	2.21
Error III	18.00	0.12	0.01	-	0.15	0.01	-	36.00	0.26	0.01	-	-
Total	53	274.08	-	-	302.81	-	-	107	576.91	-	-	-

*Significant at 5% level

APPENDIX-XXXIII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on total B uptake
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	6.419	6.419	13.87*	5.32
Replication	2.00	3.50	1.75	3.29	0.81	0.41	1.03	4.00	4.311	1.078	2.33	3.84
Factor S	2.00	36643.78	18321.89	34501.85*	37869.44	18934.72	48023.80*	4.00	74513.21	18628.30	40263.55*	3.84
Error I	4.00	2.12	0.53	-	1.58	0.39	-	8.00	3.701	0.463	-	-
Factor B	2.00	5732.79	2866.39	8873.01*	6136.41	3068.21	9041.47*	4.00	11869.20	2967.30	8959.31*	2.78
S x B interaction	4.00	602.64	150.66	466.37*	412.08	103.02	303.58*	8.00	1014.72	126.840	382.97*	2.36
Error II	12.00	3.88	0.32	-	4.07	0.34	-	24.00	7.95	0.331	-	-
Factor P	1.00	367.12	367.12	526.19*	256.32	256.32	766.60*	2.00	623.45	311.72	604.08*	3.26
S x P interaction	2.00	27.83	13.92	19.95*	12.38	6.19	18.51*	4.00	40.21	10.05	19.48*	2.63
B x P interaction	2.00	11.63	5.82	8.34*	2.42	1.21	3.63*	4.00	14.06	3.51	6.81*	2.63
SxBxP interaction	4.00	10.94	2.74	3.92*	5.18	1.30	3.88*	8.00	16.125	2.016	3.91*	2.21
Error III	18.00	12.56	0.70	-	6.02	0.33	-	36.00	18.577	0.516	-	-
Total	53	43418.79	-	-	44706.72	-	-	**107**	88131.93	-	-	-

*Significant at 5% level

APPENDIX-XXXIV

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on protein content

(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.000	0.043	0.04	0.01	5.318
Replication	2.000	35.402	17.70	4.96	31.508	15.754	3.79	4.000	66.910	16.73	4.33*	3.838
Factor S	2.000	48.743	24.37	6.84	53.408	26.704	6.42	4.000	102.151	25.54	6.61*	3.838
Error I	4.000	14.261	3.57	-	16.647	4.162	-	8.000	30.908	3.86	-	-
Factor B	2.000	3.024	1.51	1.58	2.246	1.123	0.64	4.000	5.270	1.32	0.97	2.776
S x B interaction	4.000	0.633	0.16	0.17	0.798	0.199	0.11	8.000	1.431	0.18	0.13	2.355
Error II	12.000	11.502	0.96	-	21.062	1.755	-	24.000	32.564	1.36	-	-
Factor P	1.000	0.780	0.78	3.44	0.585	0.585	0.41	2.000	1.365	0.68	0.82	3.259
S x P interaction	2.000	0.146	0.07	0.32	0.339	0.170	0.12	4.000	0.486	0.12	0.15	2.634
B x P interaction	2.000	0.070	0.03	0.15	0.059	0.029	0.02	4.000	0.128	0.03	0.04	2.634
SxBxP interaction	4.000	0.154	0.04	0.17	0.015	0.004	0.00	8.000	0.169	0.02	0.03	2.209
Error III	18.000	4.086	0.23	-	25.947	1.441	-	36.000	30.033	0.83	-	-
Total	53	118.80	-	-	152.61	-	-	107	271	-	-	-

*Significant at 5% level

APPENDIX-XXXV

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on oil content
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.39	0.39	0.17	5.318
Replication	2.00	39.50	19.75	6.65	10.96	5.48	3.68	4.00	50.45	12.61	5.66	3.838*
Factor S	2.00	87.35	43.67	14.71	90.08*	45.04	30.24*	4.00	177.43	44.36	19.90	3.838*
Error I	4.00	11.88	2.97		5.96	1.49	-	8.00	17.83	2.23	-	-
Factor B	2.00	9.46	4.73	3.29	6.74	3.37	2.27	4.00	16.21	4.05	2.77	2.776
S x B interaction	4.00	1.42	0.36	0.25	0.95	0.24	0.16	8.00	2.37	0.30	0.20	2.355
Error II	12.00	17.25	1.44		17.82	1.49	-	24.00	35.07	1.46	-	-
Factor P	1.00	0.25	0.25	0.30	0.23	0.23	0.46	2.00	0.48	0.24	0.36	3.259
S x P interaction	2.00	0.07	0.04	0.04	0.03	0.02	0.03	4.00	0.11	0.03	0.04	2.634
B x P interaction	2.00	0.32	0.16	0.19	0.45	0.23	0.45	4.00	0.77	0.19	0.29	2.634
SxBxP interaction	4.00	0.23	0.06	0.07	0.26	0.07	0.13	8.00	0.50	0.06	0.09	2.209
Error III	18.00	15.26	0.85		9.05	0.50	-	36.000	24.314	0.68	-	-
Total	53	183.00	-	-	142.53	-	-	**107**	325.92	-	-	-

*Significant at 5% level

APPENDIX-XXXVI

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on soil pH
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.01	0.01	0.17	5.32
Replication	2.00	0.50	0.25	5.90	0.24	0.12	3.81	4.00	0.74	0.18	5.00*	3.84
Factor S	2.00	0.12	0.06	1.38	0.13	0.06	2.03	4.00	0.24	0.06	1.66	3.84
Error I	4.00	0.17	0.04	-	0.13	0.03	-	8.00	0.29	0.04	-	-
Factor B	2.00	0.01	0.00	0.46	0.01	0.00	0.32	4.00	0.02	0.00	0.38	2.78
S x B interaction	4.00	0.00	0.00	0.08	0.00	0.00	0.07	8.00	0.01	0.00	0.08	2.36
Error II	12.00	0.12	0.01	-	0.15	0.01	-	24.00	0.27	0.01	-	-
Factor P	1.00	0.00	0.00	0.07	0.00	0.00	0.11	2.00	0.00	0.00	0.09	3.26
S x P interaction	2.00	0.00	0.00	0.02	0.00	0.00	0.07	4.00	0.00	0.00	0.05	2.63
B x P interaction	2.00	0.00	0.00	0.00	0.00	0.00	0.01	4.00	0.00	0.00	0.01	2.63
SxBxP interaction	4.00	0.00	0.00	0.00	0.00	0.00	0.01	8.00	0.00	0.00	0.01	2.21
Error III	18.00	0.25	0.01	-	0.35	0.02	-	36.000	0.604	0.02	-	-
Total	53	1.17	-	-	1.01	-	-	107	2.19	-	-	-

*Significant at 5% level

APPENDIX-XXXVII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on OC
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.01	0.01	15.54*	5.32
Replication	2.00	0.00	0.00	0.11	0.01	0.00	5.55	4.00	0.01	0.00	2.21*	3.84
Factor S	2.00	1.49	0.75	999.93*	1.55	0.78	1652.96*	4.00	3.04	0.76	1252.09*	3.84
Error I	4.00	0.00	0.00	-	0.00	0.00	-	8.00	0.00	0.00	-	-
Factor B	2.00	0.23	0.12	446.48*	0.29	0.15	413.40*	4.00	0.52	0.13	427.48*	2.78
S x B interaction	4.00	0.02	0.00	16.79*	0.06	0.02	44.13*	8.00	0.08	0.01	32.49*	2.36
Error II	12.00	0.00	0.00	-	0.00	0.00	-	24.00	0.01	0.00	-	-
Factor P	1.00	0.02	0.02	59.31*	0.03	0.03	23.78*	2.00	0.05	0.03	32.20*	3.26
S x P interaction	2.00	0.00	0.00	3.68*	0.03	0.01	11.85*	4.00	0.03	0.01	9.91*	2.63
B x P interaction	2.00	0.03	0.01	39.36*	0.02	0.01	8.25*	4.00	0.05	0.01	15.62*	2.63
SxBxP interaction	4.00	0.03	0.01	17.25*	0.02	0.00	3.95*	8.00	0.05	0.01	7.10*	2.21
Error III	18.00	0.01	0.00	-	0.02	0.00	-	36.000	0.029	0.00	-	-
Total	53	1.84	-	-	2.03	-	-	**107**	3.88	-	-	-

*Significant at 5% level

APPENDIX-XXXVIII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on EC
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.00	0.00	0.13	5.32
Replication	2.00	0.00	0.00	0.87	0.00	0.00	1.78	4.00	0.00	0.00	1.32	3.84
Factor S	2.00	0.00	0.00	5.75	0.00	0.00	6.93	4.00	0.01	0.00	6.34*	3.84
Error I	4.00	0.00	0.00	-	0.00	0.00	-	8.00	0.00	0.00	-	-
Factor B	2.00	0.00	0.00	2.74	0.00	0.00	0.63	4.00	0.00	0.00	1.84	2.78
S x B interaction	4.00	0.00	0.00	0.13	0.00	0.00	0.44	8.00	0.00	0.00	0.26	2.36
Error II	12.00	0.00	0.00	-	0.00	0.00	-	24.00	0.00	0.00	-	-
Factor P	1.00	0.00	0.00	0.01	0.00	0.00	0.93	2.00	0.00	0.00	0.52	3.26
S x P interaction	2.00	0.00	0.00	0.22	0.00	0.00	0.96	4.00	0.00	0.00	0.63	2.63
B x P interaction	2.00	0.00	0.00	1.53	0.00	0.00	0.04	4.00	0.00	0.00	0.71	2.63
SxBxP interaction	4.00	0.00	0.00	0.60	0.00	0.00	0.95	8.00	0.00	0.00	0.79	2.21
Error III	18.00	0.00	0.00	-	0.00	0.00	-	36.000	0.006	0.00	-	-
Total	53	0.01	-	-	0.01	-	-	**107**	0.03	-	-	-

*Significant at 5% level

APPENDIX-XXXIX

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on CEC
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.10	0.10	0.60	5.32
Replication	2.00	0.45	0.22	0.96	0.76	0.38	4.50	4.00	1.21	0.30	1.90	3.84
Factor S	2.00	117.65	58.83	250.00	95.82	47.91	564.80	4.00	213.48	53.37	333.42*	3.84
Error I	4.00	0.94	0.24	-	0.34	0.08	-	8.00	1.28	0.16	-	-
Factor B	2.00	15.50	7.75	35.78	16.23	8.12	72.93	4.00	31.73	7.93	48.39*	2.78
S x B interaction	4.00	5.94	1.49	6.86	6.92	1.73	15.55	8.00	12.86	1.61	9.81*	2.36
Error II	12.00	2.60	0.22	-	1.34	0.11	-	24.00	3.93	0.16	-	-
Factor P	1.00	0.88	0.88	2.35	2.91	2.91	4.34	2.00	3.80	1.90	3.63*	3.26
S x P interaction	2.00	1.83	0.92	2.44	4.64	2.32	3.46	4.00	6.48	1.62	3.09*	2.63
B x P interaction	2.00	0.63	0.32	0.84	1.75	0.87	1.30	4.00	2.38	0.60	1.14	2.63
SxBxP interaction	4.00	1.20	0.30	0.80	1.48	0.37	0.55	8.00	2.67	0.33	0.64	2.21
Error III	18.00	6.76	0.38	-	12.07	0.67	-	36.000	18.832	0.52	-	-
Total	53	154.39	-	-	144.27	-	-	**107**	298.76	-	-	-

*Significant at 5% level

APPENDIX-XL

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on available N in soil after harvest
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	253.18	253.18	98.89*	5.32
Replication	2.00	1.20	0.60	0.24	2.02	1.01	0.38	4.00	3.22	0.81	0.31	3.84
Factor S	2.00	15790.04	7895.02	3178.81*	15399.87	7699.93	2920.16*	4.00	31189.91	7797.48	3045.61*	3.84
Error I	4.00	9.93	2.48	-	10.55	2.64	-	8.00	20.48	2.56	-	-
Factor B	2.00	4828.33	2414.16	422.84*	4605.34	2302.67	1265.90*	4.00	9433.67	2358.42	626.54*	2.78
S x B interaction	4.00	606.72	151.68	26.57*	415.24	103.81	57.07*	8.00	1021.96	127.74	33.94*	2.36
Error II	12.00	68.51	5.71	-	21.83	1.82	-	24.00	90.34	3.76	-	-
Factor P	1.00	593.95	593.95	157.46*	776.65	776.65	469.04*	2.00	1370.60	685.30	252.50*	3.26
S x P interaction	2.00	29.18	14.59	3.87*	1.13	0.57	0.34	4.00	30.31	7.58	2.79*	2.63
B x P interaction	2.00	7.14	3.57	0.95	7.88	3.94	2.38	4.00	15.02	3.76	1.38	2.63
SxBxP interaction	4.00	60.42	15.11	4.00*	61.92	15.48	9.35*	8.00	122.35	15.29	5.63*	2.21
Error III	18.00	67.90	3.77	-	29.80	1.66	-	36.000	97.704	2.71	-	-
Total	53	22063.33	-	-	21332.23	-	-	**107**	43648.74	-	-	-

*Significant at 5% level

APPENDIX-XLI

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on available P in soil after harvest (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.86	0.86	1.32	5.318
Replication	2.00	2.49	1.25	1.68	6.60	3.30	5.90	4.00	9.09	2.27	3.50	3.838
Factor S	2.00	9.09	4.55	6.14	5.45	2.72	4.87	4.00	14.54	3.63	5.59*	3.838
Error I	4.00	2.96	0.74	-	2.24	0.56	-	8.00	5.20	0.65	-	-
Factor B	2.00	3.99	1.99	2.68	0.70	0.35	0.49	4.00	4.69	1.17	1.61	2.776
S x B interaction	4.00	0.70	0.17	0.24	3.05	0.76	1.06	8.00	3.75	0.47	0.64	2.355
Error II	12.00	8.91	0.74	-	8.61	0.72	-	24.00	17.52	0.73	-	-
Factor P	1.00	26.81	26.81	72.68*	31.96	31.96	44.96*	2.00	58.77	29.38	54.43*	3.259
S x P interaction	2.00	0.08	0.04	0.11	0.08	0.04	0.06	4.00	0.16	0.04	0.07	2.634
B x P interaction	2.00	0.94	0.47	1.27	3.93	1.96	2.76	4.00	4.87	1.22	2.25	2.634
SxBxP interaction	4.00	0.42	0.10	0.28	0.09	0.02	0.03	8.00	0.51	0.06	0.12	2.209
Error III	18.00	6.64	0.37	-	12.79	0.71	-	36.000	19.434	0.54	-	-
Total	53	63.03	-	-	75.49	-	-	**107**	139.39	-	-	-

*Significant at 5% level

APPENDIX-XLII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on available K in soil after harvest (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	27.38	27.38	0.48	5.318
Replication	2.00	24.73	12.36	1.29	56.42	28.21	0.27	4.00	81.15	20.29	0.36	3.838
Factor S	2.00	40.14	20.07	2.10	176.96	88.48	0.85	4.00	217.10	54.27	0.96	3.838
Error I	4.00	38.25	9.56	-	415.70	103.92	-	8.00	453.95	56.74	-	-
Factor B	2.00	20.57	10.29	0.28	38.10	19.05	0.64	4.00	58.67	14.67	0.44	2.776
S x B interaction	4.00	102.00	25.50	0.69	111.02	27.75	0.93	8.00	213.02	26.63	0.80	2.355
Error II	12.00	440.74	36.73	-	356.71	29.73	-	24.00	797.45	33.23	-	-
Factor P	1.00	3.02	3.02	0.05	3.70	3.70	0.13	2.00	6.72	3.36	0.08	3.259
S x P interaction	2.00	213.05	106.52	1.89	114.44	57.22	2.01	4.00	327.49	81.87	1.93	2.634
B x P interaction	2.00	10.61	5.30	0.09	1.51	0.76	0.03	4.00	12.12	3.03	0.07	2.634
SxBxP interaction	4.00	35.47	8.87	0.16	81.22	20.31	0.71	8.00	116.70	14.59	0.34	2.209
Error III	18.00	1012.22	56.23	-	513.64	28.54	-	36.000	1525.87	42.39	-	-
Total	53	1940.79	-	-	1869.43	-	-	**107**	3837.60	-	-	-

*Significant at 5% level

APPENDIX-XLIII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on available S in soil after harvest (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.09	0.09	6.58*	5.318
Replication	2.00	0.14	0.07	3.54	0.01	0.00	0.44	4.00	0.14	0.04	2.52	3.838
Factor S	2.00	51.75	25.88	1354.59	52.50	26.25	2782.40	4.00	104.25	26.06	1826.65*	3.838
Error I	4.00	0.08	0.02	-	0.04	0.01	-	8.00	0.11	0.01	-	-
Factor B	2.00	1.83	0.91	23.54	1.64	0.82	89.99	4.00	3.47	0.87	36.20*	2.776
S x B interaction	4.00	0.51	0.13	3.26	1.14	0.29	31.33	8.00	1.65	0.21	8.61*	2.355
Error II	12.00	0.47	0.04	-	0.11	0.01	-	24.00	0.57	0.02	-	-
Factor P	1.00	0.38	0.38	14.18	0.29	0.29	33.66	2.00	0.66	0.33	18.89*	3.259
S x P interaction	2.00	0.22	0.11	4.16	0.07	0.04	4.18	4.00	0.29	0.07	4.16*	2.634
B x P interaction	2.00	0.03	0.01	0.49	0.01	0.01	0.72	4.00	0.04	0.01	0.55	2.634
SxBxP interaction	4.00	0.38	0.10	3.59	0.11	0.03	3.29	8.00	0.49	0.06	3.52*	2.209
Error III	18.00	0.48	0.03	-	0.15	0.01	-	36.000	0.631	0.02	-	-
Total	53	-	-	-	-	-	-	**107**	112.41	-	-	-

*Significant at 5% level

APPENDIX-XLIV

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on exchangeable Ca in soil after harvest
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.00	0.00	0.00	5.318
Replication	2.000	0.425	0.21	0.15	4.14	2.07	1.31	4.00	4.57	1.14	0.77	3.838
Factor S	2.000	18.764	9.38	6.83	21.73	10.86	6.85	4.00	40.49	10.12	6.84*	3.838
Error I	4.000	5.495	1.37	-	6.35	1.59	-	8.00	11.84	1.48	-	-
Factor B	2.000	0.602	0.30	0.98	0.91	0.46	0.93	4.00	1.51	0.38	0.95	2.776
S x B interaction	4.000	0.571	0.14	0.47	0.60	0.15	0.30	8.00	1.17	0.15	0.37	2.355
Error II	12.000	3.672	0.31	-	5.91	0.49	-	24.00	9.58	0.40	-	-
Factor P	1.000	0.341	0.34	0.93	0.41	0.41	0.49	2.00	0.75	0.38	0.62	3.259
S x P interaction	2.000	0.250	0.13	0.34	0.75	0.37	0.44	4.00	1.00	0.25	0.41	2.634
B x P interaction	2.000	0.223	0.11	0.30	0.07	0.03	0.04	4.00	0.29	0.07	0.12	2.634
SxBxP interaction	4.000	0.743	0.19	0.50	0.51	0.13	0.15	8.00	1.26	0.16	0.26	2.209
Error III	18.000	6.625	0.37		15.15	0.84		36.000	21.771	0.60	-	-
Total	53	37.71	-	-	56.52	-	-	107	94.24	-	-	-

*Significant at 5% level

APPENDIX-XLV

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on exchangeable Mg in soil after harvest (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.00	0.00	0.02	5.32
Replication	2.00	0.00	0.00	0.29	0.00	0.00	0.12	4.00	0.01	0.00	0.20	3.84
Factor S	2.00	0.09	0.04	6.82	0.06	0.03	4.63	4.00	0.15	0.04	5.68*	3.84
Error I	4.00	0.03	0.01	-	0.03	0.01	-	8.00	0.05	0.01	-	-
Factor B	2.00	0.01	0.01	3.02	0.01	0.00	2.59	4.00	0.02	0.00	2.82*	2.78
S x B interaction	4.00	0.01	0.00	0.80	0.00	0.00	0.25	8.00	0.01	0.00	0.55	2.36
Error II	12.00	0.02	0.00	-	0.02	0.00	-	24.00	0.04	0.00	-	-
Factor P	1.00	0.00	0.00	0.98	0.00	0.00	0.01	2.00	0.00	0.00	0.56	3.26
S x P interaction	2.00	0.00	0.00	0.22	0.00	0.00	0.03	4.00	0.00	0.00	0.14	2.63
B x P interaction	2.00	0.00	0.00	0.02	0.00	0.00	0.06	4.00	0.00	0.00	0.04	2.63
SxBxP interaction	4.00	0.00	0.00	0.11	0.00	0.00	0.42	8.00	0.00	0.00	0.25	2.21
Error III	18.00	0.04	0.00	-	0.03	0.00	-	36.000	0.078	0.00	-	-
Total	53	0.20	-	-	0.16	-	-	**107**	0.36	-	-	-

*Significant at 5% level

APPENDIX-XLVI

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on available B in soil after harvest (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.01	0.01	6.28*	5.32
Replication	2.00	0.00	0.00	0.38	0.00	0.00	1.48	4.00	0.01	0.00	0.93	3.84
Factor S	2.00	0.02	0.01	6.77	0.00	0.00	1.32	4.00	0.02	0.01	4.02*	3.84
Error I	4.00	0.01	0.00	-	0.01	0.00	-	8.00	0.01	0.00	-	-
Factor B	2.00	0.51	0.25	439.01	0.54	0.27	779.43	4.00	1.05	0.26	566.63*	2.78
S x B interaction	4.00	0.01	0.00	3.08	0.00	0.00	2.88	8.00	0.01	0.00	3.01*	2.36
Error II	12.00	0.01	0.00	-	0.00	0.00	-	24.00	0.01	0.00	-	-
Factor P	1.00	0.00	0.00	4.05	0.01	0.01	7.73	2.00	0.01	0.01	5.69*	3.26
S x P interaction	2.00	0.00	0.00	0.23	0.00	0.00	0.68	4.00	0.00	0.00	0.43	2.63
B x P interaction	2.00	0.01	0.01	5.56	0.01	0.00	4.60	4.00	0.02	0.01	5.13*	2.63
SxBxP interaction	4.00	0.00	0.00	0.59	0.00	0.00	0.03	8.00	0.00	0.00	0.34	2.21
Error III	18.00	0.02	0.00	-	0.02	0.00	-	36.000	0.037	0.00	-	-
Total	53	0.59	-	-	0.60	-	-	**107**	1.20	-	-	-

*Significant at 5% level

APPENDIX-XLVII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on soil microbial biomass carbon after harvest (ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	386.73	386.73	115.33*	5.32
Replication	2.00	6.06	3.03	1.24	9.99	4.99	1.17	4.00	16.05	4.01	1.20	3.84
Factor S	2.00	16428.55	8214.27	3365.07*	17435.81	8717.91	2043.87*	4.00	-	8466.09	2524.77	3.84
Error I	4.00	9.76	2.44	-	17.06	4.27	-	8.00	26.83	3.35	-	-
Factor B	2.00	1739.16	869.58	225.34*	3054.26	1527.13	464.25*	4.00	4793.42	1198.35	335.28*	2.78
S x B interaction	4.00	646.68	161.67	41.90*	398.46	99.62	30.28*	8.00	1045.15	130.64	36.55*	2.36
Error II	12.00	46.31	3.86	-	39.47	3.29	-	24.00	85.78	3.57	-	-
Factor P	1.00	1681.81	1681.81	135.26*	1547.86	1547.86	320.76*	2.00	3229.67	1614.84	187.12*	3.26
S x P interaction	2.00	623.50	311.75	25.07*	501.33	250.67	51.95*	4.00	1124.84	281.21	32.59*	2.63
B x P interaction	2.00	94.49	47.24	3.80*	50.56	25.28	5.24*	4.00	145.05	36.26	4.20*	2.63
SxBxP interaction	4.00	1058.21	264.55	21.28*	288.54	72.14	14.95*	8.00	1346.75	168.34	19.51*	2.21
Error III	18.00	223.81	12.43	-	86.86	4.83	-	36.000	310.674	8.63	-	-
Total	53	22558.35	-	-	23430.22	-	-	107	46375.31	-	-	-

*Significant at 5% level

APPENDIX-XLVIII

Effecct of sulphur, boron and phosphorus solubilising biofertilizer on soil respiration after harvest
(ANOVA TABLE)

SOV	2016				2017			Pooled				F tab
	DF	SS	MSS	Fcal	SS	MSS	F cal	DF	SS	MSS	Fcal	
Year	-	-	-	-	-	-	-	1.00	0.86	0.86	513.57*	5.32
Replication	2.00	0.00	0.00	1.92	0.00	0.00	0.60	4.00	0.01	0.00	0.93	3.84
Factor S	2.00	14.12	7.06	8537.57*	12.84	6.42	2544.18*	4.00	26.96	6.74	4023.07*	3.84
Error I	4.00	0.00	0.00	-	0.01	0.00	-	8.00	0.01	0.00	-	-
Factor B	2.00	2.34	1.17	176.79*	2.35	1.17	264.39*	4.00	4.68	1.17	211.97*	2.78
S x B interaction	4.00	2.02	0.51	76.50*	1.59	0.40	89.59*	8.00	3.61	0.45	81.76*	2.36
Error II	12.00	0.08	0.01	-	0.05	0.00	-	24.00	0.13	0.01	-	-
Factor P	1.00	2.08	2.08	340.57*	2.20	2.20	502.02*	2.00	4.28	2.14	408.15*	3.26
S x P interaction	2.00	0.70	0.35	57.59*	0.20	0.10	22.53*	4.00	0.90	0.23	42.92*	2.63
B x P interaction	2.00	0.09	0.04	7.08*	0.08	0.04	8.85*	4.00	0.16	0.04	7.82*	2.63
SxBxP interaction	4.00	0.45	0.11	18.54*	0.57	0.14	32.17*	8.00	1.02	0.13	24.25*	2.21
Error III	18.00	0.11	0.01		0.08	0.00		36.000	0.189	0.01	-	-
Total	53	21.99	-	-	19.97	-	-	**107**	42.82	-	-	-

*Significant at 5% level