RVSKVV / Thesis / M.Sc. / No. 1574

Effect of sulphur and boron on growth and yield of onion (*Allium cepa* L.)

THESIS

Submitted to the

Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya

In partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE

In

HORTICULTURE

(VEGETABLE SCIENCE)

by

Priyanka Gurjar

Department of Vegetable Science

Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya
College of Agriculture, Gwalior (M. P.)

2018

CERTIFICATE – I

This is to certify that the thesis entitled ***"Effect of Sulphur and Boron on growth and yield of*** **Onion *(Allium Cepa*** L.**)"** *submitted in partial fulfillment of the requirement for the degree of* **MASTER OF SCIENCE** *in* **HORTICULTURE (Vegetable Science)** *of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, is a record of the bona-fide research work carried out by* **PRIYANKA GURJAR** *under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.*

No part of the thesis has been submitted for any other degree or diploma or has been published. All the assistance and help received during the course of investigations has been acknowledged by the scholar.

:

(Dr. R. LEKHI)
Chairman of the Advisory Committee

MEMBER OF STUDENT'S ADVISORY COMMITTEE

Chairman (Dr. R. Lekhi) ……………………………………..

Member (Dr A. M. Jaulkar) ……………………………………..

Member (Dr. Akhilesh Singh) ……………………………………..

Member (Dr. Rajni Sasode) ………………………………………

Member (Dr. V.B. Singh) ……………………………………..

CERTIFICATE – II

This is to certify that the thesis entitled **"*Effect of Sulphur and Boron on growth and yield of* Onion *(Allium Cepa*L.)"** *submitted by* **PRIYANKA GURJAR** *to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwaliorin partial fulfilment of the requirements for the degree of Master of Science in Agriculture in the Department of* **HORTICULTURE (Vegetable Science),***has been accepted after evaluation by the external examiner and approved by the Students Advisory Committee after an oral examination of the same.*

(Dr. R. LEKHI)
Chairman of the Advisory Committee

MEMBERS OF THE ADVISORY COMMITTEE

Chairman (Dr. R. Lekhi)……………………………………..

Member (Dr. A. M. Jaulkar)……………………………………..

Member (Dr. Akhilesh Singh) ……………………………………..

Member (Dr. Rajni Sasode) ………………………………………

Member (Dr. V.B. Singh) ……………………………………..

Head of Department ……………………………………..

Dean of the college ……………………………………..

Director of Instruction …………………………………….

ACKNOWLEDGEMENT

To me it is pleasant duty to express my heartfelt gratitude to all those who help and guided me in various ways during the course of my studies.

The words can never express indebtedness, but I take this opportunity to express my deepest and heartfelt gratitude to revered chairman of my Advisory Committee, Dr. R. Lekhi, Professor and Head, Department of Horticulture, College of Agriculture, RVSKVV, Gwalior (MP),for suggesting the problem and for his valuable guidance and scholarly advice during the course of investigation and for his healthy criticism in preparing the present manuscript of this thesis to make this task a success.

I sincerely owe my deep gratitude to the members of Advisory Committee, Dr. A.M. Jaulkar Professor, *Department* of Economics, Dr. Akhilesh Singh, Scientist, *Department of* Soil Science, Dr.Rajni Sasode, Department of Plant Pathology, Dr. V.B. Singh Professor*, Department of Statistics,* College of Agriculture*,* Gwalior for their meticulous guidance and valuable suggestions during the course of study.

I am also grateful to Dr. R. Lekhi, Professor and Head, Department of Horticulture, Dr. A.K. Barholia, Professor, Dr. K. K Yadav, Dr.(smt) Rashmi Bajpai for their help during the course of this study.

I am extremely grateful to Prof. S.K Rao, Vice Chancellor, RVSKVV, Dr. R.L. Rajput, Director Instructions and Dr. M.P. Jain Dean College of Agriculture Gwalior, for providing necessary facilities for conducting research experiment.

I enjoy proud privilege to express my sense of indebtedness with alacrity to my seniors namely, P.K.S. Gurjar Sir, Lal singh Sir, Jagdesh khushwaha, Khshboo Tondon, Deepa Soni, Dharmendr Gour, Rahul Rajput, and all my friends Whose co-operation and help in various ways brought this task to completion.

Words fail to convey my sense of profuse regards and affection to my Grand Father Shri. Munshi Singh Gurjar, My Lovely father Shri. Gajendra Singh Gurjar, mother Smt. Geeta Singh, my sisters Smt. Vandana Gurjar, and my brother Rahul Singh. I also express my gratitude to My Uncle Dr. Narendra Singh Gurjar and other family members whose incessant love, affection and encouragement brought the present task to successful completion. Finally, I express my sincere indebtedness to “God”. Who did all this through me.

Place: Gwalior. **(PRIYANKA GURJAR)**

Date : 21.05.2018

CONTENT

List of Tables

List of Figures

Abbreviations and Acronyms

Abbreviations/ Acronyms	Meaning
Ag.	Agriculture
&	And
et al.	And co-workers
@	At the rate of
B	Boron
C. D.	Critical difference
C. V.	Coefficient of variance
dSm^{-1}	Deci Siemens per meter
DAP	Day After Transplanting
^oC	Degree centigrade
Distt.	District
E	East
EC	Electrical conductivity
Fig.	Figure
FYM	Farm Yard Manure
g	Gram
>	Greater than
ha	Hectare
H I	Harvest index
i.e.	In reference to; that is
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
<	Less than
Max.	Maximum
m	Meter
mg kg^{-1}	Milli gram per kilogram
min	Minimum

mm	Milli meter
'	Minutes
Mo	Molybdenum
viz	Namely
N	Nitrogen
No.	Number
OC	Organic carbon
ppm	Parts per million
%	Per cent
K	Potassium
P	Phosphorus
PSB	Phosphorus Solubilizing Bacteria
RH	Relative humidity
R.V.S.K.V.V.	Rajmata Vijayaraje Scindia Krishi Vishwa Vidhyalaya
"	Seconds
pH	Soil reaction
S	Sulphur
SE (m)	Standard error of mean
SSP	Single Super Phosphate
Temp.	Temperature
t ha^{-1}	Tones per hectare
vs	Verses
Zn	Zinc

Chapter – I

INTRODUCTION

Onion (*Allium cepa* L.) is one of the most important vegetable crops widely grown in India and is consumed by almost everybody either raw or cooked along with spices and vegetable. In India, onion is grown in 1216.95 lakh hectare areas and its production is 19298.62 M.T. of bulb whereas in Madhya Pradesh, It is grown in 127.1 lakh hectare area and production is 21565 M.T.(NHB, 2016-17).

With the increase of 30% the production of onion in the current year is estimated at 216 lakh tonnes as against 209 lakh tonnes in 2015-16. Similarly the area under onion crop in the current year is estimated at 12.7 lakh hectares as against 13.2 lakh hectares in 2015-16 i.e. decline of about 4%over the previous year.

Onion is a sulphur loving plant and is required much for proper growth and yield of onion. Role of sulphur is particularly important in the nutrition of onion as it is constituent of allin, cycloallin and thiopropanol. In onion crop, sulphur plays a significant role in quality and development of bulbs. Probably for these reasons onion crop needs comparatively higher amounts of sulphur for proper growth, development and higher yield of bulbs. Sulphur has been found not only to increase the bulb yield of onion but also improves its quality, especially pungency and flavours (Jaggi and Dixit, 1999).

Lakkineni and Abort (1994) reported sulphur to have a key role in the plant metabolism as it is a constituent of number of organic compounds. Majority of it i.e. 80-90 per cent of total sulphur is utilised in the synthesis of sulphur amino acids, while rest is required for the synthesis of other sulphur containing compounds, taking pest in the metabolic functions of the plants.

Sulphur containing secondary compounds was not only important for nutritive value and flavours, but also for resistance against pest and disease. The yield potential of onion has not been exploited fully the sulphur as fertilizer is used in very low quantity instead of its very high requirement (Bell,1981).

The pungency in the onion bulb is due to a volatile oil known as allyl-propyl – disulphide ($C_6H_{12}S_2$) and the red colour is because of the pigment "anthocyanin" and yellow colour because of "quercetin". The nutritive value of onion varies from variety to variety. Nutritionally, fresh onion contains about 86.6 per cent moisture, 11.6 per cent carbohydrates, 0.2 to 0.5 per cent calcium, 0.05 per cent phosphorus and traces of iron and ascorbic acid **(**Dev Raj *et al.,* 2004).

Boron is one of the important micro-nutrients having different function in plants. It is one of the most widely applied micro-elements though required in small quantity (Rao and Deshpande, 1971). Its shortage in soil may hamper crop yield to a great extent. Boron is known to play many important functions in plant metabolism. In the absence of boron, proper development of meristematic tissues of plant does not take place. Boron is necessary for cell division, nitrogen and carbohydrate metabolism, salt absorption and water relation in plant. Boron is also required in the translocation of sugars, starches, nitrogen and phosphorus and synthesis of amino acids and proteins (Tisdale *et al*., 1984, Varma *et al*., 2005). Keeping the above points of view, the present investigation was conducted with following objectives-

1. To assess the influence of sulphur and boron on morphological and post harvest parameters of onion
2. To find out the combined effect of sulphur and boron on growth and yield of onion
3. To find out the optimum dose of sulphur and boron for maximizing the bulb yield of onion and
4. To work out the economics of different treatments.

CHAPTER – II

REVIEW OF LITERATURE

A comprehensive review of literature is an essential part of any scientific investigation. Apart from determining the work done in the past, assisting in delineation of insight and procedures, it forms the basis for interpretation of findings and provides a basic theoretical framework. The literature related to "**Effect of sulphur and boron on growth and yield of onion (*Allium cepa* L.)"** are presented in this chapter.

2.1: Effect of sulphur on growth, yield and quality of onion.

2.2: Effect of boron on growth, yield and quality of onion.

2.3: Interaction effect of sulphur and boron on onion crop.

2.4: Assess the economic feasibility of the different treatments

2.1: Effect of sulphur on growth, yield and quality of onion

Kumar and Singh (1995) reported that the effect of sulphur deficiency on plant growth and yield of onion. Sulphur deficiency caused a poor growth and considerably reduced yield in onion crop. On the other hand, the growth and yield were significantly better in onion plants supplied with sulphur, suggesting the sulphur deficiency to be cause of severe metabolic disorders in plants which resulted in poor growth and yield.

Singh *et al*. (1996) noticed that the mean bulb yield increased significantly with successive increase in level of sulphur application up to 80 kg/ha however, the differences were significant only upto 40 kg S/ha. Increasing levels of sulphur also increased the content and uptake of N and S in onion.

Nagaich *et al.* (1999) reported that application of 60 kg S/ha produced a significant increase in plant height, diameter of neck, number of leaves, bulb weight per plant and horizontal as well as vertical diameter of bulb over the control.

Sharma *et al.* (2002) observed that the plant height, bulb diameter, bulb yield, with the increase in S rate up to 30 kg/ha in heavy textured soils and up to 45 kg/ha in light textured soils.

Seema and Patel (2002) observed the application of 20 kg S/ha as basal dose which showed the superior effect on plant height and number of leaves per plant over absolute control.

Shakirullah *et al.* (2002) reported that maximum fresh onion yield (60.66 t/ha) with 160 kg S/ha, while minimum fresh yield (46.50 t/ha) was obtained at 20 kg S/ha. Maximum plant height (56.66 cm) was observed in plot with 100 kg S/ha and minimum plant height (56.66 cm) was observed in control. Minimum days (145.33) to harvesting were taken up by the crop receiving no sulphur. Maximum bulb weight (156.66) was examined in treatment where sulphur was applied at the rate 160 kg/ha, while minimum bulb weight (120.77 g) observed in treatment with 80 kg S/ha. Maximum pungency (6.797 points) was found in the treatment where 160 kg S/ha was applied, while it was minimum (3.567 points) in the control.

Nasreen *et al.* (2003) studied the effect of seven levels of sulphur (0, 15, 30, 45, 60, 75 and 90 kg/ha) on total dry matter (TDM) accumulation pattern, crop growth rate (CGR), relative growth rate (RGR) at various stages of growth, yield components and bulb yield of onion. Highest TDM,CGR,RGR, yield parameters and bulb yield were obtained with 45 kg S along with a blanket dose of 120 kg N, 90 kg P_2O_5, 90 kg k_2O, 5 kg Zn/ha plus 5 ton cow dung/ha. Application of 45 kg S/ha also produced marketable bulbs of 50 g size.

Nagaich and Singh (2004) reported that the maximum bulb yield of onion with the treatment combination of 80 kg K_2O + 60 kg S/ha.

Mishra and Tambi (2005) recommended the use of 40 kg S/ha to increase the sulphur percentage and bulb yield of garlic.

Joshi *et al.* (2005) conducted an experiment during rabi season 2000-01 to know the effect of sulphur application (0, 20, 40 and 60 kg/ha) on growth and yield of onion. They reported that maximum plant height, number of leaves per plant, fresh weight per plant, diameter of bulb and bulb yield (q/ha) with the use of 60 kg S/ha.

Banafar *et al.* (2005) noticed that the application of sulphur with recommended dose of fertilizer i.e. 100 kg N, 50 kg P and 50 kg K/ha improved the growth, productivity and quality of onion significantly.

Jaggi (2005) conducted a field experiment in Palampur, Himachal Pradesh, India to investigate the effects of S rates (0, 15, 30 and 60 kg/ha) and sources (S95 and Gypsum) on the yield performance of onion cv. Patna Red. he reported that the fresh and dry weights of onion, yield, plant height, number of leaves per plant and weight per 40 bulbs were increased with increasing S rates up to 30 kg/ha. Gypsum was found were effective than S 95 as the source of S.

Ullah *et al*. (2008) found that the sulphur fertilizer had significant positive influence on the weight of single bulb, diameter of bulb and bulb yield upto certain level. Weight of single bulb ranged from 21.0 to 40.0 g 2001-2002, 22.25 to 35.75 g 2002-2003 across the sulphur levels. Weight of single bulb was the highest in plants treated with 75 kg S/ha. Plant receiving 45 or 60 kg S/ha had significant effect on single bulb weight. Further increase in sulphur fertilizer tended to decrease the single weight of bulb irrespective of years. Application of S_0 kg/ha gave the lowest bulb weight. Bulb diameter varied significantly due to sulphur fertilization. Bulb diameter ranged from 3.66 to 4.51 cm in 2001-2002 and 4.5 cm to 5.18 cm in 2002- 2003 across the sulphur levels. Plants treated with 75 kg S/ha showed that the largest bulb diameter. Bulb yield differed from 10.46 to

19.75 t/ha in 2001-2002 and 10.58 to 19.88 t/ha in 2002-2003. The maximum bulb yield was observed with 75 kg S/ha followed by 60 kg S/ha in both the years. Application of sulphur at 75 kg/ha gave the yield advantage of 88.8 1% and 87.90% higher over the control in 2001-2002 and 2002-2003, respectively.

Rashid (2010) conducted an experiment to evaluate the effects of sulphur and GA_3 on the growth and yield performance of onion cv. BARI Peaj-1. The experiment included four levels of sulphur viz., 0 (control), 15, 30 and 45 kg/ha and four concentrations of GA_3 viz., 0 (control), 50, 75 and 100 ppm. The experimental findings revealed that sulphur had significant influence on plant height, number of leaves per plant, bulb diameter and length, individual bulb weight, splitted and rotten bulb, bulb dry matter content and bulb yield. The highest bulb yield (13.85 t/ha) was recorded from 30 kg S/ha, while the lowest bulb yield (11.20 t/ha) was obtained from control.

Khodadadi (2012) noticed that the sulfur fertilizer significantly increased the bulb dry matter. Maximum bulb dry matter (9.73%) was obtained with 200 kg S /ha plus thio-basillus whereas, minimum (8.23%) under control.

Mishu *et al*. (2013) reported that the different doses of sulphur application had a significant variation on fresh and dry weight of individual onion. The maximum fresh weight (31.20 g) was observed with the application of 40 kg S ha-1 followed by 20 and 60 kg S ha^{-1}. The maximum dry weight (4.68 g) was observed where land was fertilized with 40 kg S ha^{-1} followed by 20 and 60 kg S ha^{-1} with same statistical rank. Control treatment showed the minimum fresh and dry weight. The highest bulb diameter (3.97 cm) was observed with 40 kg S ha^{-1}.

Poornima *et al*. (2016) recorded significantly higher yield of onion (16.76 t ha^{-1}) with the application of S @ 30 kg ha^{-1} over 15 kg ha^{-1} (15.71 t ha^{-1}) and control (14.39 t ha^{-1}). The increase in yield was about 17.02 per cent over control.

2.2: Effect of boron on growth, yield and quality of onion

Mukhopadhyay and Chattopadhyay (1999) conducted an experiment with the effects of boron and molybdenum on growth and yield of onion in West Bengal, India. Three doses of boron (0.56, 1.12 and 2.24 kg/ha) were applied. The highest yield of bulbs (31.49 t/ha) was found at the highest level of boron. The response to molybdenum at different levels was less pronounced than that to boron. The plants at 2.24 kg B/ha and 0.40 kg Mo/ha gave the highest yield (33.06 t/ha), which was 63.3% greater than that of control.

Chattopadhyay and Mukhopadhyay (2004) reported that the foliar application of Boron at 0, 0.26, 0.546 and 1.12 kg ha^{-1} had pronounced effect of plant height and bulb production. Application of boron as boric acid @ 0.3% significantly increased bulb yield over plants that were not sprayed. The highest bulb production (28.01 t ha^{-1}) were recorded from the spray of 1.12 kg B ha^{-1}.

Manna *et al*. (2014) reported that the application of 0.5% boron significantly increased the growth (plant height, 63.93 cm and number of leaf per plant, 7.25), yield (30.74 t ha^{-1}) and quality (Total soluble solids, 13.45ºBrix and pyruvic acid 5.94 µmol.g^{-1}) of onion. Among various levels of zinc 0.5% exhibited the best growth (plant height, 67.25 cm and number of leaf per plant, 7.75), yield (33.34 t ha^{-1}) and quality (Total soluble solids, 14.57^{0} Brix and pyruvic acid, 5.86 µ mol g^{-1}) attributes of onion

Begum *et al*. (2015) reported that the application of Boron and Zn significantly influenced the growth and yield parameters of crops viz. plant height, bulb diameter, bulb length, and bulb yield for onion. Addition of Boron at 3 kg ha^{-1} and Zn 4 kg ha^{-1} gave 52% more yield benefits as compared to control.

Acharya *et al*. (2015) concluded that the application of zinc and boron shows positive effect towards the growth, yield and yield parameters of aggregatum onion. Growth parameters such as plant height, number of leaves and leaf girth were highly responsive to foliar spray and soil application of zinc sulphate and Borex. Yield and quality parameters highly responded to boron as well as zinc.

Manna and Maity (2016) noticed that the application of 0.5% boron significantly increased the growth (plant height, 63.93 cm and number of leaves per plant, 7.25), yield (30.74 t ha^{-1}) and quality (total soluble solids, 13.45 ^{0}Brix and pyruvic acid 5.94 µmol g^{-1}) of onion.

2.3: Interaction effect of sulphur and boron on onion crop

Smriti *et al.* (2002) noticed that the plant height, number of leaves, leaf length, bulb size, bulb weight and bulb yield significantly increased up to 40 kg Sulphur ha^{-1} and 1 kg Boron ha^{-1}. The neck thickness and storability decreased with increasing levels of Sulphur but increased with increasing level of Boron. The treatment combination of 40 kg Sulphur + 1 kg Boron ha^{-1} gave the highest net return and B: C ratio.

Chowdhury *et al.* (2004**)** conducted an experiment at Field Laboratory of USDA Alliums Project, Horticulture Farm, Bangladesh Agricultural University, Mymensingh, during 2003 - 2004 to study the effects of boron and sulphur on seed production of onion (*Allium cepa* L.) cv. Taherpuri. The experiment was conducted with five levels of boron, viz., 0, 1, 2, 3 and 4 kg/ha and five levels of sulphur, viz., 0, 20, 40, 80 and 160 kg/ha. The highest seed yield was recorded from 4 kg B/ha. The order of boron in Florence was 4> 3> 2> 1> 0 kg/ha. The sulphur at 80 kg/ha produced the highest seed yield. The positive effects of sulphur were found in order of 80> 40> 20> 160> 0 kg/ha. Among the treatment combinations, boron at 4 kg/ha with sulphur of 80 kg/ha produced the highest seed yield.

Paul *et al*. (2007) noticed that the application of Boron @ 1 kg ha^{-1} gave the highest yield of bulb (13.19 t ha^{-1}) and sulphur @ 30 kg ha^{-1} produced the highest yield (12.24 t ha^{-1}). However, a combined application of boron and sulphur produced the higher yield than boron and sulphur alone. Application of boron @ 1 kg ha^{-1} together with sulphur @ 30 kg ha^{-1} produced maximum yield of bulb (15.38 t ha^{-1}).

Rashid *et al*. (2007) find out the requirement of Sulphur and Boron for plant height number of leaves number of flower per umbel number of fruits per umbel higher seed yield of BARI Piqz-1 The treatments comprised five level of Sulphur at 0,20,40,80 and 100 kg /hand five levels of Boron at 0,1,3,5 and 7 kg/ha as borax The treatment combination of 100 kg 5+5 kg Boron/ha gave the highest seed yield.

Chapter-III

MATERTIAL AND METHODS

An appropriate research design and methods are the backbone of any research project. Therefore, the research methodology was designed after reviewing the relevant literature and the suggestions of members of research advisory committee and other subject matter experts of discipline. With a view to obtain higher precision in the results, the present investigation was conducted during rabi season of 2017-18. The materials used and the techniques adopted for the studies were considered as the most important ones. Therefore, the ensuring account has been prepared in the same light. A detailed account of the material used and methods followed, during the course of investigation are described in this chapter, under following heads.

3.1: EXPERIMENTAL SITE

The present experiment entitled **"Effect of sulphur and boron on growth and yield of onion (*Allium cepa* L.)",** was carried out, during *Rabi* season of 2017-18 at the horticulture nursery, College of Agriculture, Gwalior, The research farm is situated at the of 26° 13' North latitude and 76° 14' East longitude with an altitude of 211.52 meters above Mean Sea Level. The field of research farm having homogenous fertility and uniform textural make up was selected for the field experimentation.

3.2: CLIMATE AND WEATHER CONDITION

The region comes under semi-arid and sub-tropical climate with extreme weather condition having hot and dry summer and cold winter. Generally, monsoon sets in the last week of June. Annual rainfall ranges from 700 to 800 mm, most of which falls during last week of June to the middle of September. Winter rains are occasional and uncertain. The maximum temperature goes up to 47^{o}C during summer and minimum as low as 2.8^{o} C during winter. Frost also expected from the last week of December to the first week of February. Usually the monsoon arrives in the second fortnight in June and lasts till September. Occasionally, light rains are expected during winter. An average precipitation of 700 mm is usually received from July to September with few showers during winter.

The weather prevailing during season of 2017-18 was recorded from the meteorological observatory of research Farm, College of Agriculture, Gwalior and the mean values of important weather parameters for experimental period is presented in Table 3.1.

3.2.1 Temperature

It is clear from the data given in Table 3.1 that, in general, both maximum and minimum temperatures ranged between 18.8 to 41.1 and 4.0 to 24.7 during the cropping season.

3.2.2 Rainfall (mm)

The total rainfall received during the crop season of 2017-18 was 16.6mm with 4 rainy days.

3.2.3 Relative humidity (%)

The relative humidity showed considerable fluctuation throughout the growth season. The average relative humidity ranged between 15.5 to 99.2 per cent with an average of 41.65, during the cropping season.

Table 3.1: Weekly meteorological data during crop growth period (2017-18)

Met. Week	Date (2017-18)	Temperature (^{0}C)		Humidity (%)		Rainfall (mm)	Evaporati on (mm)
		Max.	Min.	Morning	Evening		
45	Nov. 5-11, 2017	32.6	15.4	86.0	46.2	000.0	4.0
46	Nov. 12-18	29.1	10.4	91.8	44.5	000.0	2.2
47	Nov. 19-25	29.8	8.6	93.5	51.4	000.0	2.8
48	Nov.-Dec.26-2	30.1	10.2	89.8	46.5	000.0	3.0
49	Dec. 3-9	28.1	8.2	88.8	49.1	000.0	3.6
50	Dec. 10-16	22.3	9.1	96.1	69.5	000.0	1.5
51	Dec. 17-23	19.2	5.1	97.5	73.7	000.0	1.2
52	Dec. 24-31	18.8	4.0	99.2	74.1	000.0	1.0
1	January 1-7, 2018	20.8	4.5	83.2	62.5	000.0	1.3
2	January 8-14	23.0	4.2	93.0	45.1	000.0	2.1
3	January 15-21	28.4	5.7	93.0	40.7	000.0	2.4
4	January 22-28	24.4	5.9	74.2	57..7	000.0	1.9
5	Jan. Fab. 29-4	26.7	8.3	87.7	49.4	000.0	.1
6	Fab.5-11	24.0	7.2	89.0	52.8	000.0	2.4
7	Fab.12-18	24.5	9.7	90.2	67.5	000.0	2.4
8	Fab.19-25	30.7	11.8	87.5	41.2	000.0	3.5
9	Fab.-Mar.26-4	32.3	14.4	81.5	37.8	000.0	5.4
10	March 5-11	32.3	11.9	74.4	42.7	000.0	5.2
11	March 12-18	34.7	1.9	54.2	38.8	000.0	5.0
12	March 19-25	34.6	15.4	71.5	30.5	000.0	6.2
13	Mar-Apr 26-1	38.0	16.1	59.5	23.4	000.0	7.8
14	April 2-8	39.3	20.7	64.3	33.0	001.2	6.6
15	April 9-15	37.1	21.0	73.0	34.2	004.6	5.6
16	April 16-22	41.1	22.6	57.5	26.4	000.0	7.9
17	April 23-29	35.8	20.9	49.0	15.5	002.0	8.5
18	April-May 30-6	40.7	24.7	58.4	28.4	008.8	8.1
				Total		16.6	

Source: Department of Meteorology, R.V.S.K.V.V. Gwalior, M. P.

3.3 SOIL CHARACTERISTICS

The soil of the experimental field was alluvial, sandy clay loam in texture. Representative soil samples of surface (0-15 cm depth) were collected from each plot before transplanting of crop with the help of soil auger for determination of physico-chemical properties of soil. The methods adopted for different analyses and results obtained are summarized in Table 3.2.

3.3.1: Chemical composition of the soil

The chemical composition of the soil collected from top 15 cm depth before transplanting of onion is presented in Table 3.2. The data pertaining to various chemical components, clearly exhibit that soil of the experimental field was sufficient in potash content, but low in organic carbon, available nitrogen and available phosphorus contents.

Table 3.2 : Chemical analysis of experimental soil

S. No.	Parameters	Values	Methods used
1	pH(1:2)	7.88	Glass Electrode pH meter (Jackson, 1973)
2	Electrical Conductivity (dS/m)	0.33	Solubridge method (Jackson, 1973)
3	Organic Carbon (%)	0.55	Walkley and Black's method (1934)
4	Available Nitrogen (kg ha^{-1})	188.40	Alakaline permanganate method (Subbiah and Asiza, 1956)
5	Available Phosphorus (kg ha^{-1})	18.56	Olsen's methods (Olsen *et al.,* 1954)
6	Available Potassium (kg ha^{-1})	328.4	Flame Photometer (Jackson, 1973)
7	Available sulphur (kg ha^{-1})	18.44	Turbidimetric method (Chesnin and Yein, 1950)

3.4 : PREVIOUS CROPPING HISTORY OF THE FIELD

The cropping history of the experimental field during the preceding three years is summarized in Table -3.3.

Table 3.3 : Cropping history of the experimental field

S. No.	Year	*Kharif*	*Rabi*
1	2014-15	Fallow	Fenugreek
2	2015-16	Fallow	Potato
3	2016-17	Fallow	Tuberose
4	2017-18	Fallow	Present experiment

3.5 : EXPERIMENTAL DETAILS

The experiment was conducted at the Horticulture Nursery of college of agriculture, Gwalior, during the *rabi* seasons of 2017-18 with 16 treatments (Combination of 4 levels of each S and B). The layout plan of the experiment is illustrated in fig. 3.2 and the details of experiments are as under:

3.5.1: Details o experimental field

1	Crop	:	Onion
2	Variety	:	Agrifound Light Red
3	Design	:	Factorial- R. B. D
4	Treatment combination	:	16 (Combination of 4 levels of each S and B)
5	No. of Replications	:	3 (Three)
6	Total Number of Plots	:	16 x 3 =48
7	Gross plot size	:	3.0 m x 2.0 m =6.0 m^2
8	Net plot size	:	2.8 m × 1.8 m =5.04 m^2
9	Distance between Rep.	:	1.0 m
10	Distance between Plot	:	0.5 m
11	Distance between Row	:	15 cm
12	Distance between plant	:	10 cm
13	Seed rate		10 kg ha^{-1}
14	Recommended fertilizers dose		N_{100} P_{60} K_{80} kg ha^{-1}.
15	Date of transplanting		02-12-2017

3.5.2: Treatments details

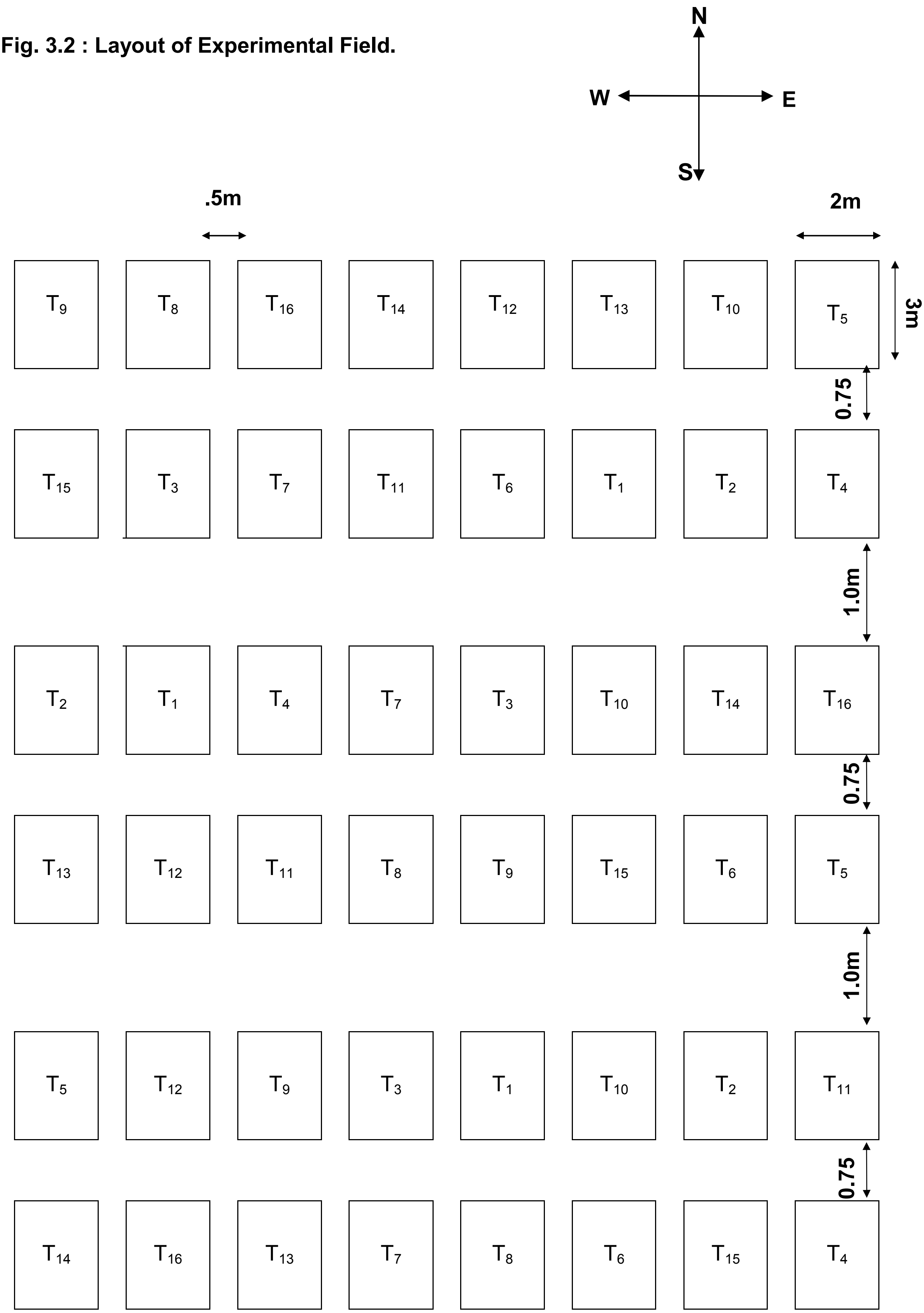
The treatments included in the investigation comprised of the sixteen combinations of 4 doses of sulphur with four doses of boron. Their notations followed in tables, layout, etc. are presented below:

	Factor	Notation
A.	**Sulphur Doses**	
	1. Control	S_0
	2. 20 kg ha^{-1}	S_1
	3. 40 kg ha^{-1}	S_2
	4. 60 kg ha^{-1}	S_3
B.	**Boron Doses**	
	1. Control	B_0
	2. 0.5 kg ha^{-1}	B_1
	3. 1.0 kg ha^{-1}	B_2
	4. 2.0 kg ha^{-1}	B_3

Treatment combinations:-

T_1: S_0B_0	T_5: S_1B_0	T_9: S_2B_0	T_{13}: S_3B_0
T_2: S_0B_1	T_6: S_1B_1	T_{10}: S_2B_1	T_{14}: S_3B_1
T_3: S_0B_2	T_7: S_1B_2	T_{11}: S_2B_2	T_{15}: S_3B_2
T_4: S_0B_3	T_8: S_1B_3	T_{12}: S_2B_3	T_{16}: S_3B_3

Fig. 3.2 : Layout of Experimental Field.



3.6: CULTURAL PRACTICES ADOPTED DURING THE EXPERIMENT

3.6.1: Planting material and procurement of seed

The experiment was conducted on the Agrifound light red cultivar of onion during *rabi* season of 2017-18.

3.6.2: Preparation of nursery

A normal size nursery bed (2.0 m x 1.0 m) was raised 15 cm above the soil surface in the departmental nursery at the end of November of 2017. While levelling, a slope of 2.0 cm was maintained from the centre to all sides for efficient drainage. Then the prepared bedding mixture was evenly spread in the form of 5.0 cm thick layer over the nursery. Rows were made 1.5 to 2.0 cm deep at 10.0 cm apart and seeds sown, covered and watered. The seedlings became ready for transplanting at 30 Days After Sowing (DAS)

3.6.3 : Field preparation

The experimental field was prepared by ploughing with a tractor drawn disc plough followed by cross harrowing and planking. A pre transplanting irrigation was given to provide adequate moisture for achieving better tilth. Two ploughing followed by planking were done for the soil of the experimental area became thoroughly pulverized for transplanting. Finally, the field was leveled and marked as per layout plan (Fig. 3.2).

3.6.4: Application of fertilizers

Fertilizers were applied as per treatment details. Nitrogen, Phosphorus and potassium were applied through Urea, Di-ammonium Phosphate (D. A. P.) and Muriate of Potash (MOP), respectively. Half dose of nitrogen, total phosphorus and potash were well mixed and applied as basal dressing before transplanting. Balance quantity of nitrogen was applied in two equal split doses of one-fourth each after first and second hand weeding followed by light irrigation.

Application of sulphur and boron were also applied in basal through elemental sulphur (90% S) and Borex (11% B), respectively.

3.6.5: Transplanting

Four week old seedlings of onion, having two to three leaves were transplanted on 02th December 2017. The seedling were lifted in clumps with the soil around the roots with the help of *khurpi* and carried to the field in basket. After separating out the individual, but, sturdy seedlings from clumps', planting was done on pre- marked spacing of 15 x 10 cm in the afternoon. When transplanting of the whole field was over, it was irrigated by flooding.

3.6.6: Gap filling

In order to maintain uniform stand of the crop in each plot, the dead seedlings were located 7 days after transplanting and replaced with new ones of the same age. This gap filling was continued till 10 days after transplanting.

3.6.7: Irrigation

The first irrigation was given on 02 December, 2017 at the time of transplanting of the seedlings there after irrigations were done as per moisture content. Overall eight irrigations were done throughout the experimental period depending upon the weather and soil conditions.

3.6.8: Inter culture operations

Totally three hand weedings were carried out during the crop growth period, to remove the weeds, since the weed problem was found more in the field.

3.6.9: Plant protection chemicals:

To control the pest and diseases, necessary plant protection measures were taken up as done as per the recommendations by using Imidaclorprid (17.8 SL) twice for thrips and Chorophyriphos (20 EC) for termite during crop growth.

3.6.10: Calendar of pre and post-transplanting operations

A calendar showing the pre and post-transplanting activities carried out in the experimental field on different dates is presented in Table 3.6:

Table 3.4: Calendar of pre and post-transplanting field operations

S. No.	Operations	Date
Pre transplanting		
1	Ploughing and leveling of land by labour for nursery raising	09-11-2017
2	Seed sowing and irrigation	04-11-2017
3	Hand weeding	20-11-2017
Post-transplanting		
4	Ploughing with tractor	17-11-2017
5	Pre transplanting irrigation	22-11-2017
6	Harrowing with tractor	28-11-2017
7	Planking or leveling	28-11-2017
8	Demarcation (layout) and application of basal dose of fertilizers of experimental field	30-11-2017
9	Transplanting of seedlings and first irrigation	**02-12-2017**
10	First hand weeding	17-12- 2017
11	Second irrigation	21-12-2017
12	First top dressing of urea	23-12-2017
13	Third irrigation	08.01.2018
14	Second top dressing of urea	10-01-2018
15	Second hand weeding	22-01-2018
16	Fourth irrigation	27.01-2018
17	Fifth irrigation	25-02-2018
18	Sixth irrigation	18-03-2018
19	Seventh irrigation	03-04-2018
20	Eighth irrigation	25-04-2018
21	Digging of onion	**05-05-2018**

3.7: OBSERVATIONAL DETAILS

The parameters relating to growth, yield attributes and yield were measured to make a critical analysis of the crop as influenced by different treatments. The technique of representative sample (five plants) was adopted for recording the observations on various morphological characters in onion.

(A) PRE- HARVEST STUDIES

- **Plant population /m row length:**

One meter long row was selected randomly at different places in each plot. Later on the numbers of plants from each such selected row were counted and average calculated at initial and harvest stage.

MORPHOLOGICAL PARAMETERS

Morphological observations on the following characters were recorded at an interval of 30 days till the complete vegetative maturity.

Plant height

The height of five randomly selected plants from each plot was measured with the help of measuring tape from soil surface upto the leaf peak, in cm, in natural condition at 30, 60, 90 and 120 days after transplanting. The average height of plants of each replication was calculated and used for tabulation and further statistical analysis.

Number of leaves per plant

All the leaves from five selected plants from each replication of all the treatments were counted at 30, 60, 90 and 120 days after transplanting. The average number of leaves per plant of each replication was recorded used for tabulation and further statistical analysis.

Length of leaves

The length of leaves of five randomly selected plants from each plot was measured with the help of scale in cm, in natural condition at 30, 60, 90 and 120 days after transplanting. The average length of different leaves in each replication was recorded, averaged and used for tabulation and further statistical analysis

(B) POST HARVEST PARAMETERS:-

Fresh weight of bulb (g)

After digging of the crop, bulb of selected twenty plants from each plot were removed and the well-developed bulb were weighed with the help of electronic balance. Thereafter, the average weight of bulb was calculated, recorded in grams and statistically analysed.

Length and diameter of bulb (cm)

The bulb taken for the study of weight was used to measure their length and circumference in the middle. The average girth of fruit (cm) was then worked out in each plot.

Yield of bulb (kg plot^{-1})

The bulbs of each net plot were weighed with the help of electronic balance; the average bulb yield per plot was recorded in kilo gram and subjected to statistical analysis.

Bulb yield per (q ha^{-1})

Based on the area of net plot, the plot-wise weight of bulb (kg) were, finally, converted into q/ha.

Dry weight of bulb (g)

The selected bulb were chopped into thin slices and a representative sample of 100 g chopped material was dried in sun and then in an electric oven at 80^{0}c to a constant weight.

3.8: ECONOMICS OF THE TREATMENT

Recommendation and adoption of any practices by cultivator depends upon its economics. Therefore, it becomes essential to work out economics of the treatments for estimating net profit/ha.

- **Cost of cultivation**

For different treatments total cost was calculated on the basis of prevailing market rate of fertilizer, field preparation, sowing of seeds, labour charges, culture and intercultural operations etc.

- **Gross return**

For different treatments gross returns was calculated on the basis of prevailing market rate of produce.

- **Net profit**

It was calculated treatment wise. The total cost of cultivation per hectare was subtracted from the gross income for computing net returns from each treatment.

$$\text{Net profit (Rs./ha)} = \text{Gross return (Rs./ha)} - \text{Cost of cultivation (Rs./ha)}$$

- **Benefit Cost Ratio (BCR)**

It was calculated treatment wise. The gross income per hectare of each treatment was divided by the cost of cultivation of respective treatments.

$$\textbf{Benefit Cost Ratio (BCR)} = \frac{\text{Gross return}}{\text{Cost of cultivation}}$$

3.9: STATISTICAL ANALYSIS

The data recorded on different observations were tabulated and analysed statistically by using the techniques of analysis of variance as suggested by Fisher (1958). Critical difference at 0.05 probability level was worked out to compare the treatments when 'F' test was significant.

Table 3.5: Template of Analysis of Variance

Sources of Variation	D.F.	S.S.	M.S.S.	F cal.	F Tab.
Replication (r)	2	SS(R)	SS(R)/2	MS(R)/ E_{Mss}	
Sulphur levels (S)	3	SS(S)	SS(F)/3	MS(S)/ E_{Mss}	
Boron doses (B)	3	SS(B)	SS(B)/3	MS(B)/ E_{Mss}	
S x B	9	SS(S X B)	SS(SX B)/9	MS(SXB)/E_{Mss}	
Error	30	SS (E)	SS (E)/30		
Total	47				

Where, r, S and Bare the number of replications, Sulphur and boron levels respectively.

Standard errors :

- S.E.(m) for S = $\sqrt{}$ESS/12
- S.E.(m) for B = $\sqrt{}$ESS/12
- S.E.(m) for interaction = $\sqrt{}$ ESS/3

Critical Difference (CD) for treatments

C.D. = S.E.(m) x $\sqrt{2}$ x t value at 30 d. f.(5%)

Where, ESS = Mean sum of square due to error

3.10: GRAPHICAL REPRESENTATION:

Data related to the progressive stage of growth are illustrated graphically, while those relating to yield attributing characters and yield/ha are depicted with the help of diagrams.

Chapter – IV

EXPERIMENTAL FINDINGS

The present chapter deals with the results of experiment laid out during Rabi season - 2017-18 at the horticulture nursery, College of Agriculture, Gwalior, (Madhya Pradesh), The observation recorded during the course of investigation were statistically analysed and finding are presented under various heads. The results of experimental findings have been illustrated with figures and diagrams wherever necessary.

(A) CROP STUDIES:

4.1. Plant population (No.)

The plant stand recorded at initial stage is presented in Table 4.1. The results revealed that the plant population was not influenced significantly by different treatment combinations of sulphur and boron. The plant population ranges between 11.25 to 11.92 m^{-1} row length at 15 DAP stage.

Table 4.1: Effect of sulphur and boron on plant population (m^{-1}) row length of onion at initial stage (15 DAP)

Treatments	S_0	S_1	S_2	S_3	B-Mean
B_0: (Control)	11.41	11.76	11.25	11.34	**11.44**
B_1 : 0.5 kg ha^{-1}	11.90	11.90	11.85	11.92	**11.90**
B_2 : 1.0 kg ha^{-1}	11.84	11.50	11.85	11.66	**11.71**
B_3 : 2.0 kg ha^{-1}	11.68	11.93	11.68	11.68	**11.74**
S-Mean	**11.71**	**11.78**	**11.66**	**11.65**	

	F-Test	S.E. (m) ±	C.D. (5%)
S	**NS**	**0.12**	**0.35**
B	**NS**	**0.12**	**0.35**
S x B	**NS**	**0.24**	**0.69**

(B) GROWTH PARAMETERS

4.2: Plant height (cm):

Plant height was recorded periodically at an interval of 30 days starting from 30^{th} day after transplanting (DAP) up to 120 DAP stage. The mean data on plant height presented in table 4.2 and fig. 4.1 indicates that it was enhanced by multi-fold with the advancement of plant growth till 90 DAP; thereafter such increase was slow up to the harvest stage.

Effect of sulphur on plant height

The variations in plant height due to sulphur level were found to be significant at 30, 60, 90 and 120 DAP of crop. Mean plant height was observed in the range of 15.41 to 17.62, 26.07 to 32.77, 37.07 to 47.50 and 42.91 to 53.74 cm under different level of sulphur at 30, 60, 90 and 120 DAP stage, respectively (Table 4.2). The increasing level of sulphur up to 40 kg ha^{-1} increased the plant height significantly thereafter height was increase in 60 kg S ha^{-1} but not cross the level of significance. Maximum height was observed with 60 kg S ha^{-1} (S_3) which was significantly higher to control and 20 kg ha^{-1} but statistically at par with 40 kg ha^{-1} at 30, 60, 90 and 120 DAP stages, respectively.

Effect of boron on plant height

Plant height ranged from 15.45 to 17.58, 26.88 to 31.69, 38.00 to 46.18 and 43.06 to 52.82 cm under different level of boron at 30, 60, 90 and 120 DAP stages, respectively. It is inferred from table 4.2, that application of boron recorded significantly higher taller plant as compared to control. Maximum height recorded with 2.0 kg B ha^{-1} treatment was comparable with 1.0 kg B ha^{-1} and both were significantly superior to control and 0.5 kg B ha^{-1} treatments at all the observation stages.

Interaction effects:

The interaction effect due to sulphur and boron on plant height was found statistically non -significant at all the growth stages.

Table - 4.2 : Effect of different levels of sulphur and boron on plant height

Plant height (cm) at 30 DAP					
Boron levels (B)	**Sulphur levels (S)**				
	S_0: (Control)	**S_1: 20 kg ha^{-1}**	**S_2: 40 kg ha^{-1}**	**S_3: 60 kg ha^{-1}**	**B-Mean**
B_0: (Control)	14.47	15.03	16.00	16.30	**15.45**
B_1 : 0.5 kg ha^{-1}	15.21	16.00	17.05	17.13	**16.35**
B_2 : 1.0 kg ha^{-1}	15.91	16.93	18.46	18.96	**17.57**
B_3 : 2.0 kg ha^{-1}	16.05	17.30	18.87	18.10	**17.58**
S-Mean	**15.41**	**16.31**	**17.60**	**17.62**	
	F-test	**S.E. (m)±**		**C.D. (5%)**	
S	**S***	**0.27**		**0.77**	
B	**S***	**0.27**		**0.77**	
S x B	**NS**	**0.54**		**1.54**	
Plant height (cm) at 60 DAP					
B_0: (Control)	24.16	26.09	28.72	28.55	**26.88**
B_1 : 0.5 kg ha^{-1}	26.41	29.05	30.81	31.66	**29.48**
B_2 : 1.0 kg ha^{-1}	26.91	31.60	33.50	34.33	**31.58**
B_3 : 2.0 kg ha^{-1}	26.81	29.89	33.51	36.55	**31.69**
S-Mean	**26.07**	**29.16**	**31.64**	**32.77**	
	F-test	**S.E. (m)±**		**C.D. (5%)**	
S	**S***	**0.79**		**2.27**	
B	**S***	**0.79**		**2.27**	
S x B	**NS**	**1.58**		**4.55**	
Plant height (cm) at 90 DAP					
B_0: (Control)	35.20	36.02	40.18	40.60	**38.00**
B_1 : 0.5 kg ha^{-1}	37.14	40.65	44.89	46.12	**42.20**
B_2 : 1.0 kg ha^{-1}	36.88	46.04	48.81	50.02	**45.44**
B_3 : 2.0 kg ha^{-1}	39.06	43.55	48.83	53.26	**46.18**
S-Mean	**37.07**	**41.57**	**45.68**	**47.50**	
	F-test	**S.E. (m)±**		**C.D. (5%)**	
S	**S***	**1.04**		**2.99**	
B	**S***	**1.04**		**2.99**	
S x B	**NS**	**2.08**		**5.98**	
Plant height (cm) at 120 DAP					
B_0: (Control)	40.38	41.33	44.88	45.67	**43.06**
B_1 : 0.5 kg ha^{-1}	42.61	45.12	51.50	51.40	**47.66**
B_2 : 1.0 kg ha^{-1}	43.83	52.82	56.00	57.38	**52.51**
B_3 : 2.0 kg ha^{-1}	44.82	49.97	56.02	60.49	**52.82**
S-Mean	**42.91**	**47.31**	**52.10**	**53.74**	
	F-test	**S.E. (m)±**		**C.D. (5%)**	
S	**S***	**1.12**		**3.23**	
B	**S***	**1.12**		**3.23**	
S x B	**NS**	**2.24**		**6.46**	

4.3: Number of leaves per plant :

Number of leaves $plant^{-1}$ a measure growth was recorded periodically at an interval of 30 DAP and the mean data are presented in table 4.3 and fig. 4.2 indicates that applications of sulphur and boron at different levels showed significantly more leaves as compared to control.

Effect of sulphur on number of leaves $plant^{-1}$

Number of leaves $plant^{-1}$ observed in the range of 6.40 to 6.91, 8.14 to 9.90, 9.49 to 10.47 and 10.46 to 14.04 under different level of sulphur at 30, 60, 90 and 120 DAP stages, respectively.

It is revealed from table 4.3, that the increasing level of sulphur up to 40 kg ha^{-1} increased the number of leaves $plant^{-1}$ significantly. However, maximum leaves $plant^{-1}$ was observed with the application of 60 kg S ha^{-1} which was significantly higher to control and 20 kg S ha^{-1}. But statistically at par with 40 kg S ha^{-1} treatment at all the observation stages.

Effect of boron on number of leaves $plant^{-1}$

Number of leaves $plant^{-1}$ ranged from 6.43 to 6.79, 8.33 to 9.74, 9.99 to 12.05 and 11.03 to 13.57 under different levels of boron at 30, 60, 90 and 120 DAP stages, respectively.

Application of boron at different levels produced significantly higher number of leaves as compared to control. Maximum leaves recorded with 2.0 kg B ha^{-1} treatment was comparable with 1.0 kg B but significantly superior to control and 0.5 kg B treatments at all the observation stages.

Interaction effects:

The interaction effect due to sulphur and boron on number of leaves $plant^{-1}$ was found statistically significant at 120 DAP stage. In this stage number of leaves ranged from 10.12 to 15.48 $plant^{-1}$ under different treatment combinations of S and B. Maximum leaves (15.48 $plant^{-1}$) was noted with S_3 x B_3 which was comparable with S_3 x B_2, S_2 x B_3, and S_2 x B_2 treatment combinations. Minimum leaves (10.12 $plant^{-1}$) was noted with control of both nutrients (S_0 x B_0).

Table- 4.3: Effect of sulphur and boron on number of leaves plant^{-1} in onion

Number of leaves plant^{-1} at 30 DAP					
Boron levels (B)	**Sulphur levels (S)**				
	S_0: (Control)	**S_1: 20 kg ha^{-1}**	**S_2: 40 kg ha^{-1}**	**S_3: 60 kg ha^{-1}**	**B-Mean**
B_0: (Control)	6.15	6.34	6.60	6.65	**6.43**
B_1 : 0.5 kg ha^{-1}	6.41	6.60	6.74	6.96	**6.68**
B_2 : 1.0 kg ha^{-1}	6.56	6.91	6.74	7.00	**6.80**
B_3 : 2.0 kg ha^{-1}	6.47	6.82	6.83	7.01	**6.79**
S-Mean	**6.40**	**6.67**	**6.73**	**6.91**	
	F-test	**S.E. (m)±**		**C.D. (5%)**	
S	**S***	**0.08**		**0.24**	
B	**S***	**0.08**		**0.24**	
S x B	**NS**	**0.17**		**0.48**	
Number of leaves plant^{-1} at 60 DAP					
B_0: (Control)	7.54	8.14	8.73	8.91	**8.33**
B_1 : 0.5 kg ha^{-1}	8.24	9.06	9.61	9.88	**9.20**
B_2 : 1.0 kg ha^{-1}	8.40	9.90	10.52	10.12	**9.73**
B_3 : 2.0 kg ha^{-1}	8.37	9.33	10.51	10.70	**9.73**
S-Mean	**8.14**	**9.11**	**9.84**	**9.90**	
	F-test	**S.E. (m)±**		**C.D. (5%)**	
S	**S***	**0.20**		**0.56**	
B	**S***	**0.20**		**0.56**	
S x B	**NS**	**0.39**		**1.12**	
Number of leaves plant^{-1} at 90 DAP					
B_0: (Control)	9.39	9.75	10.36	10.47	**9.99**
B_1 : 0.5 kg ha^{-1}	10.25	11.28	11.97	12.30	**11.45**
B_2 : 1.0 kg ha^{-1}	10.06	12.32	13.09	12.60	**12.02**
B_3 : 2.0 kg ha^{-1}	10.05	11.61	13.20	13.32	**12.05**
S-Mean	**9.94**	**11.24**	**12.16**	**12.17**	
	F-test	**S.E. (m)±**		**C.D. (5%)**	
S	**S***	**0.23**		**0.66**	
B	**S***	**0.23**		**0.66**	
S x B	**NS**	**0.46**		**1.32**	
Number of leaves plant^{-1} at 120 DAP					
B_0: (Control)	10.12	10.84	11.53	11.64	**11.03**
B_1 : 0.5 kg ha^{-1}	10.77	12.55	13.31	13.68	**12.58**
B_2 : 1.0 kg ha^{-1}	10.42	13.04	15.07	15.37	**13.48**
B_3 : 2.0 kg ha^{-1}	10.52	12.91	15.37	15.48	**13.57**
S-Mean	**10.46**	**12.33**	**13.82**	**14.04**	
	F-test	**S.E. (m)±**		**C.D. (5%)**	
S	**S***	**0.28**		**0.81**	
B	**S***	**0.28**		**0.81**	
S x B	**S***	**0.56**		**1.62**	

4.4: Length of leaves (cm)

length of leaves was recorded periodically at an interval of 30 DAP and the mean data are presented in table 4.4 and fig. 4.3, It is evident from the data presented in table 4.4, that there was a significant increase in length of leaves in different treatments of sulphur and boron as compared to control at all the stages except 30 DAP which show non–significant difference under different treatments.

Effect of sulphur on length of leaves

Length of leaves was found in the range of 6.20 to 6.36, 10.69 to 12.81, 15.18 to 18.14 and 20.66 to 25.86 under different level of sulphur at 30, 60, 90 and 120 DAP stages, respectively.

It is revealed from table 4.4, that sulphur applied treatments recorded significantly more length of leaves as compared to control. However, maximum length was observed with 60 kg S ha^{-1} which was significantly higher to control and 20 kg S ha^{-1} but was statistically at par with 40 kg S ha^{-1} treatment at 60, 90 and 120 DAP stages.

Effect of boron on length of leaves

length of leaves was noted in the range of 6.23 to 6.32, 8.33 to 9.74, 9.99 to 12.05 and 11.03 to 13.57 under different levels of boron at 30, 60, 90 and 120 DAP stages, respectively.

Application of boron at different levels produced significantly higher length of leaves as compared to control. Maximum leaves recorded with 2.0 kg B ha^{-1} treatment were comparable with 1.0 kg B but significantly superior to control and 0.5 kg B treatments at 60, 90 and 120 DAP stages.

Interaction effects:

The interaction effect due to sulphur and boron on length of leaves was found statistically non- significant at 30, 60, 90 and 120 DAP stage.

Table- 4.4: Effect of sulphur and boron on length of leaves (cm) in onion

Length of leaves (cm) at 30 DAP					
Boron levels (B)	**Sulphur levels (S)**				
	S_0: (Control)	**S_1: 20 kg ha^{-1}**	**S_2: 40 kg ha^{-1}**	**S_3: 60 kg ha^{-1}**	**B-Mean**
B_0: (Control)	6.07	6.14	6.39	6.31	**6.23**
B_1 : 0.5 kg ha^{-1}	6.15	6.28	6.41	6.42	**6.32**
B_2 : 1.0 kg ha^{-1}	6.24	6.01	6.15	6.40	**6.20**
B_3 : 2.0 kg ha^{-1}	6.32	6.49	6.16	6.32	**6.32**
S-Mean	**6.20**	**6.23**	**6.28**	**6.36**	
	F-test	S.E. (m)±		C.D. (5%)	
S	**NS**	**0.10**		**0.28**	
B	**NS**	**0.10**		**0.28**	
S x B	**NS**	**0.20**		**0.57**	
Length of leaves (cm) at 60 DAP					
B_0: (Control)	10.30	10.97	11.07	10.97	**10.83**
B_1 : 0.5 kg ha^{-1}	11.01	12.15	11.89	13.11	**12.04**
B_2 : 1.0 kg ha^{-1}	10.82	12.98	13.10	13.35	**12.56**
B_3 : 2.0 kg ha^{-1}	10.63	11.89	13.76	13.79	**12.52**
S-Mean	**10.69**	**12.00**	**12.45**	**12.81**	
	F-test	S.E. (m)±		C.D. (5%)	
S	**S***	**0.37**		**1.06**	
B	**S***	**0.37**		**1.06**	
S x B	**NS**	**0.73**		**2.12**	
Length of leaves (cm) at 90 DAP					
B_0: (Control)	14.13	15.25	16.35	16.69	**15.61**
B_1 : 0.5 kg ha^{-1}	15.44	16.98	18.01	18.51	**17.24**
B_2 : 1.0 kg ha^{-1}	15.50	18.04	18.78	18.67	**17.75**
B_3 : 2.0 kg ha^{-1}	15.68	17.48	18.72	18.70	**17.64**
S-Mean	**15.18**	**16.94**	**17.97**	**18.14**	
	F-test	S.E. (m)±		C.D. (5%)	
S	**S***	**0.41**		**1.18**	
B	**S***	**0.41**		**1.18**	
S x B	**NS**	**0.82**		**2.36**	
Length of leaves (cm) at 120 DAP					
B_0: (Control)	18.84	20.73	22.96	23.50	**21.51**
B_1 : 0.5 kg ha^{-1}	20.52	21.93	25.39	26.62	**23.62**
B_2 : 1.0 kg ha^{-1}	21.07	26.78	26.64	26.79	**25.32**
B_3 : 2.0 kg ha^{-1}	22.21	21.20	26.73	26.52	**24.17**
S-Mean	**20.66**	**22.66**	**25.43**	**25.86**	
	F-test	S.E. (m)±		C.D. (5%)	
S	**S***	**0.59**		**1.69**	
B	**S***	**0.59**		**1.69**	
S x B	**NS**	**1.18**		**3.39**	

(C) YIELD ATTRIBUTING CHARACTERS

The yield of onion crop is a combined effect of the yield characters of the plants *viz.* length of bulb, diameter of bulb and fresh weight of bulb. In general, better crop growth results in favorable yield contributing characters ultimately resulting in higher yield. The data on different yield contributing characters were recorded at harvest stage and analyzed statistically and ANOVA table given in appendix VI and mean data are presented in table 4.5-4.7.

(I) Length of bulb (cm)

It is evident from the data presented in table 4.5, that there was a significant increase in length of bulb in different treatments of sulphur and boron as compared to control.

Effect of sulphur on length of bulb

Length of bulb of onion was observed in the range of 3.62 to 4.48 cm under different levels of sulphur. It is clear from Table 4.5, that the increasing level of sulphur up to 40 kg ha^{-1} increased the bulb length significantly. However, maximum length (4.48 cm) was observed with 60 kg S ha^{-1} (S_3) which was significantly higher to control and 20 kg S ha^{-1} but statistically at par with 40 kg S ha^{-1}.

Effect of boron on length of bulb

The analysis of variance showed that levels of boron also affected the bulb length significantly. Under different level of boron, bulb length ranged from 3.71 to 4.43 cm. Application of 2.0 kg B ha^{-1} resulted significantly maximum bulb length as compared to control and 0.5 kg B ha^{-1} but show at par length with 1.0 kg B ha^{-1} treatment.

Interaction effects:

The interaction effect due to sulphur and boron on bulb length of onion was found statistically non significant at harvest stage.

Table – 4.5: Effect of sulphur and boron on length of bulb (cm) of onion

Treatments	S_0	S_1	S_2	S_3	B-Mean
B_0: (Control)	3.45	3.57	3.85	3.97	**3.71**
B_1 : 0.5 kg ha^{-1}	3.56	3.87	4.23	4.39	**4.01**
B_2 : 1.0 kg ha^{-1}	3.72	4.35	4.80	4.74	**4.40**
B_3 : 2.0 kg ha^{-1}	3.74	4.40	4.75	4.81	**4.43**
S-Mean	**3.62**	**4.05**	**4.41**	**4.48**	

	F-Test	S.E. (m) ±	C.D. (5%)
S	**S***	**0.07**	**0.21**
B	**S***	**0.07**	**0.21**
S x B	**NS**	**0.15**	**0.43**

(II) Diameter of bulb (cm)

Mean data of bulb diameter of onion are presented in table 4.6, which revealed that there was a significant increase in diameter of bulb in different treatments of sulphur and boron as compared to control.

Effect of sulphur on diameter of bulb

Diameter of bulb of onion was recorded in the range of 4.09 to 5.00 cm under different levels of sulphur. It is clear from Table 4.6, that the increasing level of sulphur up to 40 kg ha^{-1} increased the bulb diameter significantly. However, maximum diameter (5.00 cm) was observed with 60 kg S ha^{-1} (S_3) which was significantly higher to control and 20 kg S ha^{-1} but statistically at par with 40 kg S ha^{-1}. Application of 40 kg S also showed significantly more bulb diameter as compared to control and 20 kg S ha^{-1}.

Effect of boron on diameter of bulb

Application of boron also affected bulb diameter significantly as compared to control. Under different level of boron, bulb diameter noted in the range of from 4.07 to 4.98 cm. Application of 2.0 kg B ha^{-1} showed significantly maximum bulb diameter as compared to control and 0.5 kg B ha^{-1} but show at par diameter in 1.0 kg B ha^{-1} treatment. Application of 1.0 kg B ha^{-1}also recorded significantly higher bulb diameter as compared to control and 0.5 kg B ha^{-1}.

Interaction effects:

The interaction effect due to sulphur and boron on diameter of bulb was found statistically significant. Diameter of bulb ranged from 3.92 to 5.36 cm under different treatment combinations of S and B. Maximum diameter (5.36 cm) was noted with S_3 x B_3 which was comparable with S_2 x $B_{2,}$ S_3 x $B_{2,}$ and S_2 x $B_{3,}$ S_3 x $B_{1,}$ S_1 x $B_{3,}$ and S_1 x B_2 treatment combinations. Minimum diameter (3.92 cm) was noted with control of both nutrients (S_0 x B_0).

Table – 4.6: Effect of sulphur and boron on diameter of bulb (cm) of onion

Treatments	S_0	S_1	S_2	S_3	B-Mean
B_0: (Control)	3.92	3.99	4.15	4.23	**4.07**
B_1 : 0.5 kg ha^{-1}	4.07	4.07	4.85	5.15	**4.54**
B_2 : 1.0 kg ha^{-1}	4.15	4.98	5.32	5.28	**4.93**
B_3 : 2.0 kg ha^{-1}	4.22	5.05	5.28	5.35	**4.98**
S-Mean	**4.09**	**4.52**	**4.90**	**5.00**	

	F-Test	S.E. (m) ±	C.D. (5%)
S	**S***	**0.08**	**0.24**
B	**S***	**0.08**	**0.24**
S x B	**S***	**0.17**	**0.49**

(III) Fresh weight of bulb (g)

It is an important yield attributing character which determines the bulb size and quality of bulb produced. It is inferred from the data given in table 4.7; that the different levels of sulphur and boron were able to alter fresh weight to some extent.

Effect of sulphur on fresh weight of bulb

A significant increase was noted in fresh weight of onion bulb under different levels of sulphur as compared to the control. It is observed in the range of 62.55 to 78.32 g under different treatments.

Increasing level of sulphur up to 40 kg ha^{-1} increased the fresh weight of bulb significantly. However maximum fresh weight (78.32 g) was observed with the application of 60 kg S ha^{-1} (S_3) was comparable with 30 kg S ha^{-1} (S_2) treatment and both were significantly higher to control and 20 kg S ha^{-1} .

Effect of boron on fresh weight of bulb

fresh weight of bulb observed in the range of 64.88 to 76.55 g under different levels of boron at harvest stage.

It is inferred from table 4.7, that application of boron produced significantly large bulb as compared to control. Application of higher dose of boron i.e. 1.0 and 2.0 kg B ha^{-1} recorded 13.21 and 15.77 g significantly more fresh weight of onion bulb as compared to control.

Interaction effects:

The interaction effect due to sulphur and boron on fresh weight of bulb was found statistically non- significant.

Table – 4.7: Effect of sulphur and boron on fresh weight of bulb (g) of onion

Treatments	S_0	S_1	S_2	S_3	B-Mean
B_0: (Control)	60.32	62.37	67.34	69.50	**64.88**
B_1 : 0.5 kg ha^{-1}	62.12	67.66	74.00	76.77	**70.14**
B_2 : 1.0 kg ha^{-1}	63.36	76.03	81.11	82.84	**75.84**
B_3 : 2.0 kg ha^{-1}	64.40	77.02	80.60	84.16	**76.55**
S-Mean	**62.55**	**70.77**	**75.76**	**78.32**	

	F-Test	S.E. (m) ±	C.D. (5%)
S	**S***	**1.50**	**4.33**
B	**S***	**1.50**	**4.33**
S x B	**NS**	**3.01**	**8.66**

(D) BULB YIELD :

In the present invesigation, the yield of the onion crop is expressed in terms of bulb yield. The data recorded on bulb yield in kg plot^{-1} was converted into bulb yield q ha^{-1} by multiplying conversion factor as per net plot and presented in table 4.8 and graphically illustrated through fig. 4.7.

(I) bulb yield (kg plot^{-1}):

Table 4.8, indicated that there was a significant response in bulb yield due to different levels of sulphur and boron as compared to respective control.

Effect of sulphur on bulb yield

Bulb yield varied from 14.56 to 16.68 kg plot^{-1} under different levels of sulphur. The increasing level of sulphur increased the bulb yield significantly up to 40 kg ha^{-1}. Maximum yield (16.68 kg plot^{-1}) was observed with the application of 60 kg S ha^{-1} (S_3) which was significantly higher to control and 20 kg S ha^{-1} but statistically at par with 40 kg S ha^{-1}.

Effect of boron on bulb yield

Bulb yield observed in the range of 14.74 to 16.65 kg plot^{-1} under different levels of boron. It is inferred from Table 4.8, that application of boron produced significantly higher bulb yield over control. Maximum yield (16.65 kg plot^{-1}) was observed with 2.0 kg B ha^{-1} which was significantly higher to control and 0.5 kg B ha^{-1} treatment but was comparable with 1.0 kg B ha^{-1}.

Interaction effects:

The interaction effect due to sulphur and boron on bulb yield was found statistically non- significant.

Table-4.8: Effect of different levels of sulphur and boron on bulb yield of onion

Treatments	Bulb yield	
	Bulb yield (kg plot^{-1})	**Bulb yield (q ha^{-1})**
Sulphur levels (S)		
S_0: (Control)	14.56	289.0
S_1: 20 kg ha^{-1}	15.56	308.8
S_2: 40 kg ha^{-1}	16.63	329.9
S_3: 60 kg ha^{-1}	16.68	331.1
S.E. (m)±	**0.27**	**5.4**
C.D. (5%)	**0.79**	**15.6**
Boron levels (B)		
B_0: (Control)	14.74	292.4
B_1 : 0.5 kg ha^{-1}	15.45	306.5
B_2 : 1.0 kg ha^{-1}	16.61	329.5
B_3 : 2.0 kg ha^{-1}	16.65	330.3
S.E. (m) ±	**0.27**	**5.4**
C.D. (5%)	**0.79**	**15.6**
Interactions (S X B)	**NS**	**NS**

Table – 4.8 (A): Effect of sulphur and boron on bulb yield (kg plot^{-1}) of onion

Treatments	S_0	S_1	S_2	S_3	B-Mean
B_0: (Control)	13.66	14.79	15.11	15.40	**14.74**
B_1 : 0.5 kg ha^{-1}	14.39	15.11	16.11	16.17	**15.45**
B_2 : 1.0 kg ha^{-1}	15.04	16.00	17.45	17.92	**16.61**
B_3 : 2.0 kg ha^{-1}	15.16	16.35	17.84	17.24	**16.65**
S-Mean	**14.56**	**15.56**	**16.63**	**16.68**	

	F-Test	S.E. (m) ±	C.D. (5%)
S	**S***	**0.27**	**0.79**
B	**S***	**0.27**	**0.79**
S x B	**NS**	**0.55**	**1.58**

Table – 4.8 (B): Effect of sulphur and boron on bulb yield (q ha^{-1}) of onion

Treatments	S_0	S_1	S_2	S_3	B-Mean
B_0: (Control)	271.1	293.4	299.7	305.6	**292.4**
B_1 : 0.5 kg ha^{-1}	285.5	299.9	319.6	320.9	**306.5**
B_2 : 1.0 kg ha^{-1}	298.5	317.5	346.2	355.6	**329.5**
B_3 : 2.0 kg ha^{-1}	300.8	324.4	354.0	342.1	**330.3**
S-Mean	**289.0**	**308.8**	**329.9**	**331.1**	

	F-Test	S.E. (m) ±	C.D. (5%)
S	**S***	**5.4**	**15.6**
B	**S***	**5.4**	**15.6**
S x B	**NS**	**10.9**	**31.3**

(II) bulb yield (q ha^{-1}):

The data on bulb yield (q ha^{-1}) presented in table 4.8 & 4.8 (A) indicated that there was a significant response in bulb yield due to different levels of sulphur and boron as compared to respective control.

Effect of sulphur on bulb yield

Bulb yield varied from 289.0 to 331.1 q ha^{-1} under different levels of sulphur. The increasing level of sulphur increased the bulb yield significantly up to 40 kg ha^{-1} thereafter also increase but not cross the level of significance. Maximum yield (331.1 q ha^{-1}) was observed with the application of 60 kg S ha^{-1} (S_3) which was 14.57 and 7.22 per cent significantly higher to control and 20 kg S ha^{-1} but was statistically at par with 40 kg S ha^{-1}. Application of 40 kg S ha^{-1} (S_2) also recorded 14.15 and 6.83 per cent significantly higher bulb yield as compared to control and 20 kg S ha^{-1} treatments.

Effect of boron on bulb yield

Bulb yield observed in the range of 292.4 to 330.3 q ha^{-1} under different levels of boron. It is inferred from Table 4.8, that application of boron produced significantly higher bulb yield over control. Maximum yield (330.3 q ha^{-1}) was observed with 2.0 kg B ha^{-1} which was 12.96 and 7.76 per cent significantly higher to control and 0.5 kg B ha^{-1} treatment but was comparable with 1.0 kg B ha^{-1} treatment. Application of 1.0 kg B ha^{-1} also recorded 12.68 and 7.50 per cent significantly higher bulb yield as compared to control and 0.5 kg B ha^{-1} treatments.

Interaction effects:

The interaction effect due to sulphur and boron on bulb yield (q ha^{-1}) was found statistically non- significant.

(E) QUALITATIVE STUDIES:

In the present investigation quality of the produce was estimated in terms of dry weight per 100 g of bulb. Data on dry weight was subjected to statistically analysis and presented in table 4.9.

Effect of sulphur on dry weight

Under different levels of sulphur dry weight was recorded in the range of 8.42 to 9.54 per cent and sulphur treated plots show significantly higher dry weightas compared to control. It is clear from the data that the increasing levels of sulphur up to 40 kg ha^{-1} increased the dry weight significantly but maximum value (9.54 g/100g fresh weight) was recorded with 60 kg S ha^{-1} which was significantly higher to control and 20 kg S ha^{-1} but was statistically at par with 40 kg S ha^{-1}.

Effect of boron on dry weight

Dry weight of bulb observed in the range of 8.38 to 9.43 per cent under different levels of boron. It is inferred from table 4.9, that application of boron produced significantly higher dry weight as compared to control. Application of 1.0 and 2.0 kg B ha^{-1} recorded 9.31 and 9.43 g dry weight per 100 g fresh weight of onion bulb and both were significantly higher as compared to control and 0.5 kg B ha^{-1} treatment.

Interaction effects:

The interaction effect due to sulphur and boron on dry weight was found statistically non- significant.

Table - 4.9 : Effect of sulphur and boron on dry weight of bulb/100g fresh weight of onion

Treatments	S_0	S_1	S_2	S_3	B-Mean
B_0: (Control)	8.08	8.20	8.53	8.69	**8.38**
B_1 : 0.5 kg ha^{-1}	8.37	8.38	9.65	9.83	**9.05**
B_2 : 1.0 kg ha^{-1}	8.54	9.25	9.60	9.85	**9.31**
B_3 : 2.0 kg ha^{-1}	8.68	9.38	9.86	9.80	**9.43**
S-Mean	**8.42**	**8.80**	**9.41**	**9.54**	

	F-Test	S.E. (m) ±	C.D. (5%)
S	**S***	**0.11**	**0.30**
B	**S***	**0.11**	**0.30**
S x B	**NS**	**0.21**	**0.61**

(F) ECONOMICAL PARAMETERS:

Economics of onion as affected by different doses of S and B is given in table 4.10.

The maximum gross income Rs. 331100, 330300 and 355600 ha^{-1} in onion crop was recorded under S_3 (60 kg ha^{-1}),B_3 (2.0 kg ha^{-1}) and S_3 x B_2 was higher than all other treatments. Whereas minimum gross income of was recorded under control of respective nutrients.

The maximum net return Rs. 259485, 259860 and 283163 ha^{-1} was obtained from S_2 (40 kg ha^{-1}),B_2 (1.0 kg ha^{-1}) treatments and S_3 x B_2 combination and it was higher than all other treatments. Minimum net income (Rs 202520 ha^{-1}) was recorded under control S_0 x B_0.

Under different levels of sulphur, maximum B:C ratio (4.69) was obtained from S_2 (40 kg ha^{-1}), followed by S_3 (60 kg ha^{-1}), with 4.64 B:C ratio. Whereas minimum B:C ratio (4.22) under control treatment.

Under different levels of boron, maximum B:C ratio (4.73) was obtained from B_2 (1.0 kg ha^{-1}), followed by B_3 (2.0 kg ha^{-1}) with 4.67 B:C ratio. Whereas minimum B:C ratio (4.27) was recorded under control.

Under different treatment combination (interactions) of sulphur and boron, maximum B:C ratio (4.91) was obtained from S_3 x B_2 followed by S_2 x B_3 and S_2 x B_2 with 4.88 and 4.84 B:C ratio. Whereas minimum B:C ratio (3.95) under control of both nutrients (S_0 x B_0).

Table 4.10: Economics of different treatments of S and B under onion crop

Treatments	Cost of cultivation excluding treatments (Rs. ha^{-1})	Treatment cost (Rs. ha^{-1})	Total Cost of cultivation (Rs. ha^{-1})	Bulb yield (q ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B : C ratio
Sulphur levels (S)							
S_0: 0 kg ha^{-1}	68550	0	68550	289.0	289000	220450	4.22
S_1: 20 kg ha^{-1}	68550	932	69482	308.8	308800	239318	4.44
S_2: 40 kg ha^{-1}	68550	1865	70415	329.9	329900	**259485**	**4.69**
S_3: 60 kg ha^{-1}	68550	2797	71347	331.1	331100	259353	4.64
Boron levels (B)							
B_0: (Control)	68550	0	68550	292.4	292400	223850	4.27
B_1 : 0.5 kg ha^{-1}	68550	545	69095	306.5	306500	237405	4.44
B_2 : 1.0 kg ha^{-1}	68550	1090	69640	329.5	329500	**259860**	**4.73**
B_3 : 2.0 kg ha^{-1}	68550	2180	70730	330.3	330300	259570	4.67
Treatment combination							
T_1-S0B0	68550	0	68550	271.07	271070	202520	3.95
T_2-S0B1	68550	545	69095	285.50	285500	216405	4.13
T_3-S0B2	68550	1090	69640	298.47	298470	228830	4.29
T_4-S0B3	68550	2180	70730	300.83	300830	230100	4.25
T_5-S1B0	68550	932	69482	293.40	293400	223918	4.22
T_6-S1B1	68550	1477	70027	299.90	299900	229873	4.28
T_7-S1B2	68550	2022	70572	317.50	317500	246928	4.50
T_8-S1B3	68550	3112	71662	324.37	324370	252708	4.53
T_9-S2B0	68550	1865	70415	299.73	299730	229315	4.26
T_{10}-S2B1	68550	2410	70960	319.60	319600	248640	4.50
T_{11}-S2B2	68550	2955	71505	346.23	346230	274725	4.84
T_{12}-S2B3	68550	4045	72595	353.97	353970	281375	4.88
T_{13}-S3B0	68550	2797	71347	305.57	305570	234223	4.28
T_{14}-S3B1	68550	3342	71892	320.93	320930	249038	4.46
T_{15}-S3B2	68550	3887	72437	355.60	355600	**283163**	**4.91**
T_{16}-S3B3	68550	4977	73527	342.10	342100	268573	4.65

Sale price of onion bulb seed = (Rs. 1000 q^{-1})
Details of cost of cultivation are given in appendix -1

Fig 4.1: Effect of sulphur and boron on plant population (m^{-1}) row length of onion at initial stage (15 DAP)

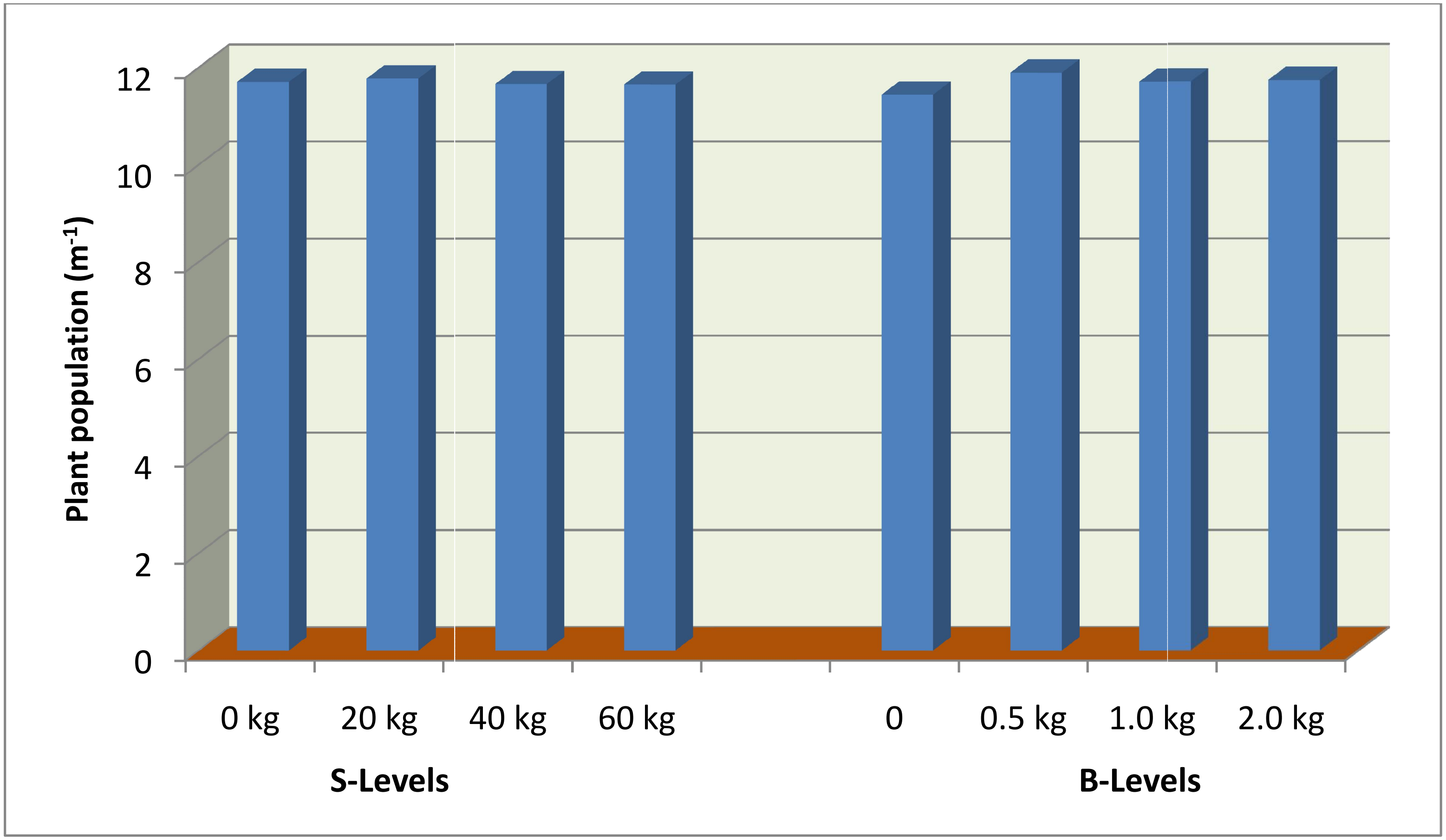
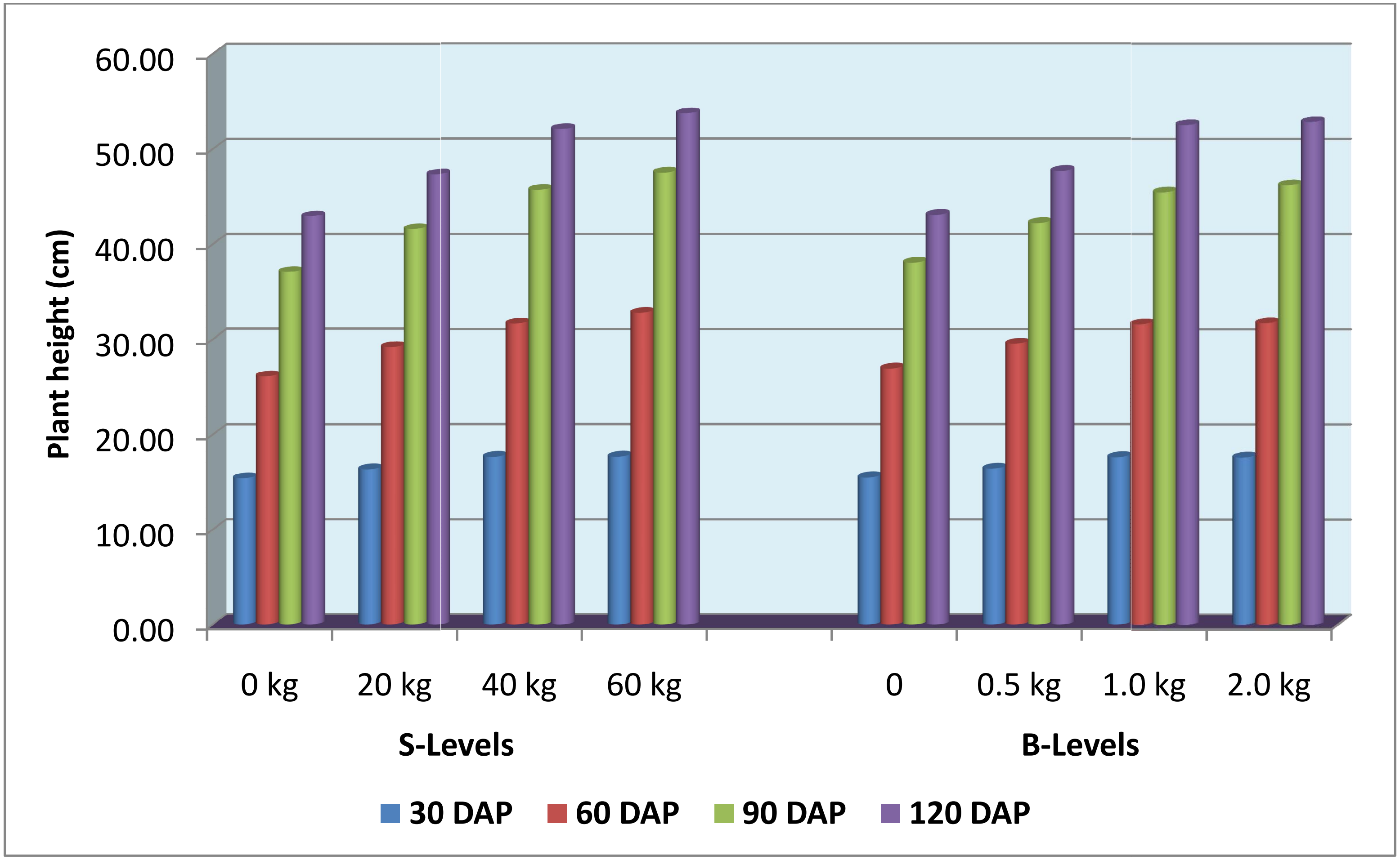


Fig - 4.2: Effect of different levels of sulphur and boron on plant height (cm)



Chapter – V
DISCUSSION

The present investigation entitled **"Effect of sulphur and boron on growth and yield of onion (*Allium cepa* L.)"** was conducted during rabi seasons of 2017-18 at the horticulture nursery, College of Agriculture, Gwalior.

During the course of discussion an effort has been made to establish relationship between various plant characters, yield and quality of the crop. However, on the basis of the findings, an attempt has also been made in the foregoing pages to explain the possible reasons of variability obtained due to different treatments. Wherever necessary, findings of other workers have also been quoted to support the results of the present investigation.

5.1: Effect of sulphur on

5.1.1: Growth and yield attributes characters:

The application of different levels of sulphur with recommended dose of NPK, increased almost all growth and yield attributing characters significantly, however, the trend of increase was towards positive direction.

It is revealed that the increasing level of sulphur up to 40 kg ha^{-1} increase the plant height, number of leaves $plant^{-1}$ and length of leaves significantly at 30, 60,90 and 120 DAP stage. Maximum values were observed with the application of sulphur 60 kg ha^{-1} (S_3) which was significantly higher to control and 20 kg S ha^{-1} but statistically at par with 40 kg S ha^{-1} treatment at all the observation stages.

The yield attributes viz. diameter of bulb, length of bulb and fresh weight of bulb increased due to increasing levels of sulphur.

Application of 60 kg S ha^{-1} showed the best results in different yield attributes component but the effect of 40 kg S ha^{-1} was found at par with diameter of bulb, length of bulb and fresh weight of bulb.

The probable reason may be that adequate supply of all the nutrients, particularly sulphur which resulted in greater accumulation of carbohydrates, amino acids and their translocation to the productive organs, which, in-turn improved in all the growth and yield attributing characters. The present results are in agreement with the findings of Nagaich *et al.* (1998) and Salimath (1990).

In general, it was observed that the significant increase in yield attributes due to higher levels of sulphur which applied with recommended dose of NPK. This may be attributed to the vigorous vegetative growth of the crop under the higher sulphur level, which resulted in adequate supply of photosynthetic in the formation of leaves, bulb and development of bulb

Our results confirm the finding of Sharma *et al.* (2002), Joshi *et al.* (2005), and Mishu *et al*. (2013). Earlier Nagaich *et al.* (1999) and Singh *et al*. (1996) also observed that the application of sulphur in onion @ 40 and 60 kg ha^{-1} significantly increased bulb yield and its attributes.

5.1.2: bulb yield

The bulb yield is a cumulative effect of different growth and yield attributing characters. Significant increase in bulb yield was recorded with incremental S levels. The results reported in foregoing pages, revealed that the increasing level of sulphur increase the bulb yield significantly up to 40 kg ha^{-1} there was yield also increase but not cross the levels of significance. Maximum bulb yield (331.1 q ha^{-1}) was observed with the application of 60 kg S ha^{-1} (S_3) which was 14.57 and 7.22 per cent significantly higher to control and 20 kg S ha^{-1} but was statistically at par with 40 kg S ha^{-1}. Application of 40 kg S ha^{-1} (S_2) also recorded 14.15 and 6.83 per cent significantly higher bulb yield as compared to control and 20 kg S ha^{-1} treatments.

The increase in bulb yield with application of S might be due to increased uptake of nutrients by the crop which might have enhanced the synthesis and translocation of photosynthates to the bulbs and storage organs of onion.

There was a significant increase in bulb yield due to sulphur application suggesting that the soil was medium in sulphur that resulted in yield difference. Moreover, increase in bulb yield under 20 or *40* kg S/ha might be due to production of taller plants with higher number of leaves leading to increase formation of vegetative structure for nutrient absorption and photosynthesis and increased production of assimilates to fill the sink, resulting in increased bulb size and weight. The findings confirm the results of Joshi *et al.* (2005) Banafar *et al.* (2005), Mishu *et al*. (2013) and Poornima *et al*. (2016).

The highest yield of onion bulb was also reported by Nasreen *et al*. (2003) and Nasreen and Huq (2005) at 45 kg S ha^{-1} while Smriti *et al*. (2002) was obtained from 40 kg S ha^{-1}.

5.1.3: Dry weight of onion

Under different levels of sulphur dry weight was recorded in the range of 8.42 to 9.54 per cent and sulphur treated plots show significantly higher dry weight as compared to control. It is clear from the data that the increasing levels of sulphur up to 40 kg ha^{-1} increased the dry weight significantly but maximum value (9.54 g/100g fresh weight) was recorded with 60 kg S ha^{-1} which was significantly higher to control and 20 kg S ha^{-1} but was statistically at par with 40 kg S ha^{-1}. The findings of present investigation are supported by Khodadadi (2012) and Mishu *et al*. (2013).

Jaggi (2005) also observed the significant increase of dry weight of bulb with 30 kg S ha^{-1}. Meena and Singh (1998) showed that S fertilization significantly enhanced the dry weight of onion tops and bulbs.

5.2: Effect of boron

5.1.1: Growth and yield attributes characters:

Application of boron recorded significantly higher taller plant and higher number of leaves and its length as compared to control. Maximum height and number of leaves noted with 2.0 kg ha^{-1} treatment but was statistically at par with its lower dose of @ 1.0 kg ha^{-1} at all the observation stages.

Chowdhury *et al*. (2004) also reported that the number of leaves per plant increased with the application of boron at higher dose.

Howlader *et al*. (2010) stated that the higher number of leaves per plant produced by 30% extra boron application might be due to boron helps in other nutrient availability encouraging more vegetative growth.

The results reported in foregoing pages, revealed that the yield attributes viz. diameter of bulb, length of bulb and fresh weight of bulb increased due to increasing levels of boron.

Maximum values were observed with 2.0 kg B ha^{-1} which was significantly higher to control and 0.5 kg B ha^{-1} but was statistically at par with 2.0 kg B ha^{-1} levels. The findings confirm the results of Chattopadhyay and Mukhopadhyay (2004), and Begum *et al*. (2015).

5.2.2: Onion bulb yield

Application of boron produced significantly higher bulb yield over control. Maximum yield (330.3 q ha^{-1}) was observed with 2.0 kg B ha^{-1} which was 12.96 and 7.76 per cent significantly higher to control and 0.5 kg B ha^{-1} treatment but was comparable with 1.0 kg B ha^{-1} treatment. Application of 1.0 kg B ha^{-1} also recorded 12.68 and 7.50 per cent significantly higher bulb yield as compared to control and 0.5 kg B ha^{-1} treatments.

The increase in yield might be due to role of boron in biosynthesis of indole acetic acid (IAA) and especially due to its role in initiation of primordial for reproductive parts and partitioning of photosynthates towards them, which resulted in better fruiting. The findings of present investigation are supported by Mukhopadhyay and Chattopadhyay (1999), and Acharya *et al*. (2015). This result is closely related to Mishra *et al.* (1990). They stated that yield of onion was mostly enhanced by Boron.

5.2.3: Dry weight of onion

Dry weight of bulb observed in the range of 8.38 to 9.43 per cent under different levels of boron. It is inferred from table 4.9, that application of boron produced significantly higher dry weight as compared to control. Application of 1.0 and 2.0 kg B ha^{-1} recorded 9.31 and 9.43 g dry weight per 100 g fresh weight of onion bulb and both were significantly higher as compared to control and 0.5 kg B ha^{-1} treatment. Gamelli *et al.* (2000) narrated that dry weight of bulb was significantly increased by applying Boron.

5.3: Interaction effect of sulphur and boron

5.3.1: Growth and yield attributes characters

Significant interaction effect of sulphur and boron was recorded only number of leaves $plant^{-1}$ at 120 DAP stage and diameter of bulb. Maximum leaves (15.48 $plant^{-1}$) were noted with S_3 x B_3 which was comparable with S_3 x B_2, S_2 x B_3 and S_2 x B_2 treatment combinations. Minimum leaves (10.12 $plant^{-1}$) were noted with control of both nutrients (S_0 x B_0).

Maximum diameter (5.36 cm) was noted with S_3 x B_3 which was comparable with S_2 x B_2, S_3 x B_2, and S_2 x B_3, S_3 x B_1, S_1 x B_3, and S_1 x B_2 treatment combinations. Minimum diameter (3.92 cm) was noted with control of both nutrients (S_0 x B_0). The findings confirm the results of Paul *et al*. (2007).

5.4: Economics :

The results reported in foregoing pages, revealed the maximum gross and net return obtained under 40 kg S ha^{-1} followed by 60 kg S ha^{-1} whereas, maximum B:C ratio (3.58) was obtained under (40 kg S ha^{-1}) followed by 60 kg S ha^{-1} treatment. This may be because of the difference in yield between 40 and 60 kg S ha^{-1} was at par and cost of cultivation was lesser with 40 kg S ha^{-1}.

The results reported in foregoing pages, revealed the maximum net return and B:C ratio obtained under 1.0 kg B ha^{-1} followed by 2.0 kg B ha^{-1}. This may be because of the difference in yield between 1.0 and 2.0 kg B/ha was non- significantly differ from each other.

Under different treatment combination (interactions) of sulphur and boron, maximum B:C ratio (4.91) was obtained from S_3 x B_2 followed by S_2 x B_3 and S_2 x B_2 with 4.88 and 4.84 B:C ratio. Whereas minimum B:C ratio (3.95) under control of both nutrients (S_0 x B_0). Similar findings were also reported by Smriti *et al.* (2002)

CHAPTER – VI
SUMMARY AND CONCLUSION

Onion is a sulphur loving plant and the latter is required much for proper growth and yield of earlier. Role of sulphur is particularly important in the nutrition of onion as it is constituent of allin, cycloallin and thiopropanol. The productivity of onion in Madhya Pradesh is very low. Among various factors responsible for the low yield of onion, inadequate and imbalanced use of fertilizer as well as no use of secondary and micronutrients (sulphur and boron) are the major factors. Keeping in view, the present investigation entitled **"Effect of sulphur and boron on growth and yield of onion (*Allium cepa* L.)"** was conducted during Rabi season of 2017-18 at the horticulture nursery, College of Agriculture, Gwalior with the following objectives:

1. To assess the influence of sulphur and boron on morphological and post harvest parameters of onion
2. To find out the combined effect of sulphur and boron on growth and yield of onion
3. To find out the optimum dose of sulphur and boron for maximizing the bulb yield of onion and
4. To work out the economics of different treatments.

The soil of the experimental site was Sandy Clay Loam in texture, low in available nitrogen and medium in phosphorus, potassium and sulphur. The experimental crop onion (Cv Agrifound light red) was transplanted on 2nd December 2017 and digging on 5th May 2018. The study involve Sixteen treatment combinations consisting of four sulphur levels viz. S_0: Control, S_1: 20 kg S ha^{-1}, S_2: 40 kg S ha^{-1}, S_3: 60 kg S ha^{-1} and four doses of Boron, i.e. B_0: Control, B_1 : 0.5 kg B ha^{-1}, B_2: 1.0 kg B ha^{-1} and B_3: 2.0 kg B ha^{-1} in factorial randomized block design with three replications. The recommended dose of fertilizer (RDF) adopted was 100:60: 80 kg of N: P: K ha^{-1}. All data collected were subjected to the analysis of variance and significant means separated where appropriate by the least significant difference at 0.05 probability level

The results obtained from present study are summarized as below:

The application of different levels of sulphur and boron with recommended dose of NPK, increased almost all growth and yield attributing characters significantly, however, the trend of increase was towards positive direction.

6.1: Effect of sulphur

- It is revealed that the increasing level of sulphur up to 40 kg ha^{-1} increased the plant height, number of leaves $plant^{-1}$ and length of leaves significantly at 30, 60, 90 and 120 DAP stages. Maximum values were observed with the application of sulphur 60 kg ha^{-1} (S_3) which was significantly higher to control and 20 kg S ha^{-1} but statistically at par with 40 kg S ha^{-1} treatment at all the observational stages.

- The yield attributes viz. diameter of bulb, length of bulb and fresh weight of bulb increased due to increasing levels of sulphur. Application of 60 kg S ha^{-1} showed the best results in different yield attributes component but the effect of 40 kg S ha^{-1} was found at par with diameter of bulb, length of bulb and fresh weight of bulb.

- Significant increase in bulb yield was recorded with incremental S levels. The results reported in foregoing pages, revealed that the increasing level of sulphur increased the bulb yield significantly up to 40 kg ha^{-1} thereafter yield also increase with 60 kg S ha^{-1} treatment but not cross the levels of significance. Maximum bulb yield (331.1 q ha^{-1}) was observed with the application of 60 kg S ha^{-1} (S_3) which was 14.57 and 7.22 per cent significantly higher to control and 20 kg S ha^{-1} respectively, but was statistically at par with 40 kg S ha^{-1}.

- Application of 40 kg S ha^{-1} (S_2) also recorded 14.15 and 6.83 per cent significantly higher bulb yield as compared to control and 20 kg S ha^{-1} treatments.

- Under different levels of sulphur dry weight was recorded in the range of 8.42 to 9.54 per cent and sulphur treated plots show significantly higher dry weight as compared to control. It is clear from the data that the increasing levels of sulphur up to 40 kg ha^{-1} increased the dry weight significantly but maximum value (9.54 g/100g fresh weight) was recorded with 60 kg S ha^{-1} which was significantly higher to control and 20 kg S ha^{-1} but was statistically at par with 40 kg S ha^{-1}.

6.2: Effect of boron

- Application of boron recorded significantly higher taller plant and higher number of leaves and its length as compared to control. Maximum height and number of leaves noted with 2.0 kg ha^{-1} treatment but was statistically at par with its lower dose of @ 1.0 kg ha^{-1} at all the observation stages.

- The results reported in foregoing pages, revealed that the yield attributes viz. diameter of bulb, length of bulb and fresh weight of bulb increased due to increasing levels of boron. Maximum values were observed with 2.0 kg B ha^{-1} which was significantly higher to control and 0.5 kg B ha^{-1} but was statistically at par with 2.0 kg B ha^{-1} levels.

- Application of boron produced significantly higher bulb yield over control. Maximum yield (330.3 q ha^{-1}) was observed with 2.0 kg B ha^{-1} which was 12.96 and 7.76 per cent significantly higher to control and 0.5 kg B ha^{-1} treatment but was comparable with 1.0 kg B ha^{-1} treatment. Application of 1.0 kg B ha^{-1} also recorded 12.68 and 7.50 per cent significantly higher bulb yield as compared to control and 0.5 kg B ha^{-1} treatments.

- Dry weight of bulb observed in the range of 8.38 to 9.43 per cent under different levels of boron. It is inferred from table 4.9, that application of boron produced significantly higher dry weight as compared to control. Application of 1.0 and 2.0 kg B ha^{-1} recorded 9.31 and 9.43 g dry weight per 100 g fresh weight of onion bulb and both were significantly higher as compared to control and 0.5 kg B ha^{-1} treatment.

6.3: Interaction effect of sulphur and boron

- Significant interaction effect of sulphur and boron was recorded only number of leaves plant^{-1} at 120 DAP stage and diameter of bulb. Maximum leaves (15.48 plant^{-1}) were noted with S_3 x B_3 which was comparable with S_3 x B_2, S_2 x B_3 and S_2 x B_2 treatment combinations. Minimum leaves (10.12 plant^{-1}) were noted with control of both nutrients (S_0 x B_0).

- Maximum diameter (5.36 cm) was noted with S_3 x B_3 which was comparable with S_2 x B_2, S_3 x B_2, and S_2 x B_3, S_3 x B_1, S_1 x B_3, and S_1 x B_2 treatment combinations. Minimum diameter (3.92 cm) was noted with control of both nutrients (S_0 x B_0).

6.4: Economics:

- The results reported in foregoing pages, revealed the maximum gross and net return obtained under 40 kg S ha^{-1} followed by 60 kg S ha^{-1} whereas, maximum B:C ratio (3.58) was obtained under (40 kg S ha^{-1}) followed by 60 kg S ha^{-1} treatment. This may be because of the difference in yield between 40 and 60 kg S ha^{-1} was at par and cost of cultivation was lesser with 40 kg S ha^{-1}.

- The results reported in foregoing pages, revealed the maximum net return and B:C ratio obtained under 1.0 kg B ha^{-1} followed by 2.0 kg B ha^{-1}. This may be because of the difference in yield between 1.0 and 2.0 kg B/ha was non- significantly differ from each other.

- Under different treatment combination (interactions) of sulphur and boron, maximum B:C ratio (4.91) was obtained from S_3 x B_2 followed by S_2 x B_3 and S_2 x B_2 with 4.88 and 4.84 B:C ratio. Whereas minimum B:C ratio (3.95) under control of both nutrients (S_0 x B_0).

CONCLUSION:

With a view to draw definite conclusion from the results of present investigation, the bulb yield, net returns and B:C ratio have been the major considerations.

- The increasing level of sulphur up to 40 kg ha^{-1} increased bulb yield significantly over control and 20 kg S. however, Maximum yield (331.1 q/ha) was noted with 60 kg S but was statistically at par with 40 kg S.

- Under different levels of B, Maximum bulb yield (330.3 q/ha) was noted with 2.0 kg B was statistically at par with 1.0 kg B and both were significantly higher with control and 0.5 kg B levels.

- Under different levels of sulphur, maximum net return (259485/-) and B:C ratio (4.69) was noted with 40 kg/ha followed by 60 and 20 kg/ha levels Whereas minimum under control treatment.

- Under different levels of boron, maximum net return (259860/-) and B:C ratio (4.73) was noted with1.0 kg B/ha followed by 2.0 and 0.5 kg B/ha levels Whereas minimum under control treatment.

- Under different treatment combination of sulphur and boron, maximum B:C ratio (4.91) was obtained from S_3 x B_3 followed by S_2 x B_3 and S_2 x B_2 with 4.88 and 4.84 B:C ratio. Whereas minimum B:C ratio (3.95) under control of both.

From present study, it can be concluded that application of 40 kg sulphur and 1.0 kg Boron may be beneficial for higher bulb yield and net return as well as B;C ratio in onion in Gwalior district.

BIBLIOGRAPHY

Acharya, Umesh, Rimal, N. S., Venkatesan, K. Saraswathi, T. and Subramanian, K.S. (2015) Response on growth, yield and quality parameters of multiplier onion with different doses and method of zinc and boron application. *International Journal of Agronomy and Agricultural Research,* **6** (4) : 59-67.

Banafar, R.N.S. and Gupta, N.K. (2005) Influence of soil and foliar application of sulphur on growth, yield and quality of onion. *In:* National Seminar on Agro-Technology, Quality, Processing and Export of Spices. Pp 67.

Begum, R., Jahiruddin, M., Kader, M. A., Haque, M. A. and Hoque, A. M. (2015) Effects of zinc and boron application on onion and their residual effects on Mungbean**.** *Progressive Agriculture*, **26** : 90-96.

Bell, A. A. (1981) Biochemical mechanism of disease resistance. *Ann. Rev. Plant Physiol.* **32:** 2 1-81.

Chattopadhyay, S. B. and Mukhopadhyay, T. P. (2004) Response of boron and molybdenum as foliar feeding on onion in tarai soil of West Bengal. *Environment and Ecology,* **22 (4)**: 784-787.

Chesnin, L. and C.H. Yien (1950) Turbidimetric determination of available sulphates. *Proc. Soil Sci. Soc. Am*. **14**:149-151

Chowdhury, S.H., Ali, M. S., Hossain, M. A., Ahmed, M. U. and Hoque, M. M. (2004). Effect of boron and sulphur on yield and quality of onion seed. *Bangladesh J. Agric. Sci.,* 22: 179-184.

Dev Raj., Huddar, A.G. and Gupta, N.K. (2004) Effect of dehydration temperatures on the quality characteristics of dehydrated onion rings during storage. *Udyanika,* **10(4)**: 47-52.

Fisher, R.A. (1958) Skeleton Analysis of Variance Book “Design of Experiment”.

Gamelli, E. L., Hanna, and Hadi, E. L. (2000) The effect of some foliar fertilizers application on growth, bulb yield, quality and storage ability of Giza 20 onion cultivar (*Allium capa* L). *Annals of Agril. Sci. Moshtohor*. **38** (3): 1727-1737.

Howlader, M. M., Kamruzzaman, M. M., Chowdhury M. E. K. and Yousuf, .M. N. (2010) Effect of phosphorus, potassium and boron on onion seed production. Research Report. Spices Research Centre. *Bangladesh Agric. Res. Inst*. pp.13-17.

Jackson, M.L. (1973). Soil Chemical Analysis, Prentice Hall of Indian Pvt. Ltd. New Delhi.

Jaggi, R. (2005) Sulphur levels and sources affecting yield and yield attributes in onion (*Allium cepa*). Ind. J. Agric. Sci. **75**:154-156.

Jaggi, R. C. and Dixit, S. P. (1999) Onion (*Allium cepa* L.) responses to sulphur in representative vegetable growing soils of Kangra Vabiley of Himachal Pradesh. *Indian J. Agric. Sci.* **69:** 289-291.

Joshi, R. P., Rajoria, U. K. and Bose, U. S. (2005) National Seminar on Agro-Technology, Quality, Processing and Export of Spices. Pp 64.

Khodadadi, Mohsen (2012) Effect of Sulfur Application Rates on Some Quality Traits and Yield of Iranian Onion Varieties. *International Research Journal of Applied and Basic Sciences,* **3** (6): 1215-1217.

Kumar, A. and Singh, O. (1995) Effect of sulphur deficiency on plant growth and yield of onion. *Indian J. Agric. Res.* **29** (3): 127-130.

Lakhineni, K. C. and Abrot, Y. P. (1994) Sulphur requirement of crop plants. *Physiol. Analysis Fert. News*. 39 (3): 11-18.

Manna, D. and Maity, T. K. (2016) Growth, yield and bulb quality of onion (*Allium cepa* L.) in response to foliar application of boron and zinc, *Journal of Plant Nutrition*, **39**(3): 438-441.

Manna, D., Maity, T. K. and Ghosal, A. (2014) Influence of foliar application of boron and zinc on growth, yield and bulb quality of onion (*Allium cepa* L.). *Journal of Crop and Weed,* **10** (1): 53-55.

Meena, O. and Singh, D. (1998) Effect of sulpur and zinc application on onion yield and sulpur and zinc uptake in three soil orders. *J. Ind. Soc. Soil Sci.* **46**:636-640.

Mishra, H. P., Singh, K.P. and Yadav, J.P. (1990) Influence of zinc, iron, boron and manganese and their uptake on onion *(Allium cepa* L.) growth in calcareous soil. *Haryana J. Hort. Sci.,* **19** (1-2): 153-159.

Mishra, S.N. and Tambi, K.N. (2005) Yield and quality of garlic as influenced by sulphur fertilization. National Seminar on Agro-Technology, Quality, *Processing and Export of Spices*. Pp 82.

Mishu, H. M., Ahmed, Fahim, Rafil, M. Y., Golam, Faruq and Latif, M. A. (2013) Effect of sulphur on growth, yield and yield attributes in onion (*Allium cepae* L.) *Australian journal of crop science*, **7(9)**: 1416-1422.

Mukhopadhyay, A. and Chattopadhyay. S. K. (1999) Effects of boron and molybdenum on growth and yield of onion. *Plant Sci. Lett.*, **14**:193-198.

Nagaich, K. N. and Singh, V.B. (2004) Response of onion to potash and sulphur. National Seminar on Agro-Technology, Quality, Processing and Export of Spices. Pp 136.

Nagaich, K. N., Tridevi, S.K. and Lekhi, Rajesh (1998) Effect of sulphur and potassium fertilization on onion (*Allium cepa* L.). *South Indian Hort.*, **46** (5 & 6) : 266 – 271.

Nagaich, K.N., Trivedi, S.K. and Lekhi, R. (1999) Effect of sulphur and potassium fertilizer in onion. *Hort. J.* **12** (1): 25-31.

Nasreen, S, Haq, S. M. I. and Hossain, M.A. (2003) Sulphur effects on growth responses and yield of onion. *Asian J. Plant Sci.* **2**:897-902.

Nasreen, S., and Haq S. M. I. (2005) Effect of sulphur fertilization on yield, sulphur content and uptake by onion. *Ind J Agric Res*. **39**:122-127.

NHB (2016-17). National Horticulture Board*,* database, **www.nhb.gov.in.**

Olsen, S.R., Cole, C.B., Waternable, P.S. and Dean, L.A. (1954). Estimation of available phosphous in soil by extraction with solution of sodium bicarbonate. U.S.D.A. Circular. M. 937.

Paul, J. K., Halder, B. C. and Khan, M. A. (2007) Effects of boron and sulphur on the growth and yield of onion. *Journal of Science technology (Dinajpur)* **, 5** : 60-66.

Poornima, K. S., Mamatha, N. and Ramesh, H.S. (2016).Effect of potassium and sulphur on yield and yield attributes of onion and chilli intercrops in a Vertisol. *Asian J. Soil Sci.*, **11** (1) : 58-61 :

Rao, V.J.M. and Deshpande, R. (1971) Effect of micro-nutrients (copper and boron) on the growth and yield of onion (*Allium cepa* L.). *Indian J. Agric. Res.,* 5(4):257-260.

Rashid, A. M., Khan A. M. and Ullah M. A. (2007) Effect of sulphur and boron on onion seed production. Research Report. *Spices Research Center. Bangladesh Aric. Res. Inst*., 05-09.

Rashid, H.A. (2010) Effect of different levels of sulphur and Giblerlic Acid on yield and pungency of onion. Sarhad J Agric (Pakistan). **28** (2): 144-147.

Salimath, S.S. (1990). Studies on status of potassium and sulphur in soils and their effect on onion (*Allium cepa* L.). M.Sc. (Ag.) Thesis, University of Agricultural Sciences, Dharwad, Karnataka (India).

Seema, S.D.T. and Patel, K.P. (2002). Effect of sulphur and foliar spray of micro-nutrients on growth, yield and quality of onion. *In:* National Sem. On Production technology and export potential of Onion. Oct., 4-5. pp. 16-18.

Shakirullah, Mahammad, Ishtiaq, Rashan, Ali and Shah, S.T.H. (2002) Effect of different levels of sulphur on yield and pungency of onion. *Sarhad J Agric.* **18** (2): 183-187.

Sharma, M. P., Singh, A. and Gupta, J.P. (2002). Sulphur status and response of onion (*Allium cepa L.)* to applied sulphur in soils of Jammu districts. *Indian J. Agril. Sci.* **72** (1): 26-28.

Singh, H., Singh, S. and Singh, V. (1996). Response of onion (*Allium cepa* L.) to nitrogen and sulphur. *Annals of Agric. Res.* **17** (4): 441-444.

Smriti, S., Kumar, R. and Singh, S. K. (2002) Effect of sulphur and boron nutrition on growth, yield and quality of onion (*Allium cepae* L**.)** *Journal* of *Applied Biology, **12** : 40-46.*

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for the estimation of available nitrogen in soils. *Corr. Sci.*, **25:** 259-260.

Tisdale, S.L., W.L. Nelson and J.D. Beaton. (1984) Soil Fertility and Fertilizers. 4th Ed. MacMillan Pub. Comp., New York. p 285.

Ullah, M.H., Huq, S.M.I., Alam, M.D.U. and Rahman, M.A. (2008) Impacts of sulphur levels on yield, storability and economic return of onion**.** *Bangladesh J. Agril. Res.* **33**(3) : 539-548.

Verma, D. P., Sharma, B. R., Chadha, A.P.S., Bajpai, H.K. and Bhadauria, U.P.S. (2005) Effect of boron in soil on physiological and biochemical characteristics, yield and quality of onion. *Adv. Plant Sci.*, **9**(2): 39-41.

Walkley, A. and Black, C.S. (1934). An examination of degrifareff methods for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Sci*., **37**: 29-38.

APPENDICES

Appendix-I (A) : Details of cost of cultivation excluding treatments .

S. No.	Particulars	Quantity	Rate (Rs./ha)	Amount (Rs./ha)
Pre transplanting				
1	Ploughing and ridge bed for nursery preparation	05	200	1000
2	Cost of seed	10 kg	560/-	5600
3	Cost of irrigation	02	500	1000
4	Cost of weeding	1/5 labour	200/- labour	1000
	Total			**8600**
Post transplanting				
1	Ploughing	02	2000	4000
2	Harrowing & Levelling	02	1500	3000
3	Layout, ridge and manuring	05 labour	200/- labour	1000
4	Cost of transplanting charges	36 labour	200	7200
5	Cost of RDF (NPK)	100:60:80	-	6250
6	Cost of labour charges for fertilizers	05	200	1000
7	Cost of irrigation	08	1250	10000
8	Cost of 3 weeding	30 labour	20	6000
9	Cost of insecticide for thrips and termite	02 times	1250	2500
10	Cost of digging	50	200	10000
11	Cost of cutting	20	200	4000
12	Packing and transporting charges	1	5000	5000
	Total			**59950**
	G. TOTAL			**68550**

Appendix-I (B) : Details of cost of cultivation of different treatments of sulphur and Boron

S. No.	Particulars	Quantity of elemental –S (90%S) (kg ha^{-1})	Rate (Rs./kg)	Amount (Rs./ha)
Sulphur levels				
1	S_0: 0 kg ha^{-1}	0	42	0
2	S_1: 20 kg ha^{-1}	22.2	42	932
3	S_2: 40 kg ha^{-1}	44.4	42	1865
4	S_3: 60 kg ha^{-1}	66.6	42	2797
Boron levels				
S. No.	**Particulars**	**Quantity of Borex (11% B) (kg ha^{-1})**	**Rate (Rs./kg)**	**Amount (Rs./ha)**
1	B_0: (Control)	0	120	0
2	B_1 : 0.5 kg ha^{-1}	4.55	120	545
3	B_2 : 1.0 kg ha^{-1}	9.10	120	1090
4	B_3 : 2.0 kg ha^{-1}	18.20	120	2180

APPENDIX - II : Analysis of variance for plant population

Variation due to	D. F.	At 15 DAP		At maturity		Table value of F at 5%	Table value of F at 1%
		MSS	Variance Ratio (F_{cal})	MSS	Variance Ratio (F_{cal})		
Replication	2	0.024	**0.14**	0.181	**1.75**		
Treatments	11	0.143	**0.82**	0.115	**1.11**		
Sulphur levels (S)	3	0.040	**0.23** NS	0.075	**0.72** NS	2.92	4.51
Zinc levels (Zn)	2	0.434	**2.50** NS	0.198	**1.91** NS	2.92	4.51
S x Zn	6	0.080	**0.46** NS	0.100	**0.97** NS	2.05	2.75
Error	22	0.174		0.103			

APPENDIX - III : Analysis of variance for plant height

Variation due to	D. F.	30 DAP		60 DAP		90 DAP		120 DAP		Table value of F at 5%	Table value of F at 1%
		MSS	V.R. (F_{cal})	MSS	V. R. (F_{cal})	MSS	V.R. (F_{cal})	MSS	V.R. (F_{cal})		
Replication	2	1.839	**2.14**	5.399	**0.72**	14.332	**1.11**	17.727	**1.17**		
Treatments	15	5.552	**6.46**	35.754	**4.79**	92.225	**7.14**	117.896	**7.81**		
Sulphur levels (S)	3	13.828	**16.09****	105.886	**14.17****	258.468	**20.01****	287.920	**19.08****	2.92	4.51
Zinc levels (Zn)	3	12.846	**14.95****	61.364	**8.21****	166.608	**12.90****	255.850	**16.95****	2.92	4.51
S x Zn	9	0.362	**0.42** NS	3.841	**0.51** NS	12.017	**0.93** NS	15.236	**1.01** NS	2.05	2.75
Error	30	0.859		7.472		12.919		15.091			

*** Significant at 5%   ** Significant at 1%**

APPENDIX - IV : Analysis of variance for number of leaves /plant

Variation due to	D. F.	30 DAP		60 DAP		90 DAP		120 DAP		Table value of F at 5%	Table value of F at 1%
		MSS	V.R. (F_{cal})	MSS	V. R. (F_{cal})	MSS	V.R. (F_{cal})	MSS	V.R. (F_{cal})		
Replication	2	0.004	**0.04**	0.305	**0.67**	0.582	**0.92**	0.005	**0.01**		
Treatments	15	0.188	**2.22**	2.823	**6.18**	5.387	**8.49**	11.079	**11.72**		
Sulphur levels (S)	3	0.535	**6.32****	8.150	**17.85****	13.315	**20.97****	32.844	**34.76****	2.92	4.51
Zinc levels (Zn)	3	0.346	**4.09***	5.246	**11.49****	11.150	**17.56****	16.605	**17.57****	2.92	4.51
S x Zn	9	0.020	**0.24** NS	0.240	**0.53** NS	0.823	**1.30** NS	1.982	**2.10***	2.05	2.75
Error	30	0.085		0.457		0.635		0.945			

APPENDIX - V : Analysis of variance for length of leaves

Variation due to	D. F.	30 DAP		60 DAP		90 DAP		120 DAP		Table value of F at 5%	Table value of F at 1%
		MSS	V.R. (F_{cal})	MSS	V. R. (F_{cal})	MSS	V.R. (F_{cal})	MSS	V.R. (F_{cal})		
Replication	2	0.046	**0.40**	1.216	**0.75**	0.356	**0.18**	5.872	**1.41**		
Treatments	15	0.059	**0.50**	4.342	**2.68**	6.923	**3.43**	23.568	**5.68**		
Sulphur levels (S)	3	0.064	**0.55**NS	10.281	**6.35****	22.097	**10.94****	71.840	**17.30****	2.92	4.51
Zinc levels (Zn)	3	0.046	**0.39** NS	7.854	**4.85****	11.816	**5.85****	30.583	**7.37****	2.92	4.51
S x Zn	9	0.061	**0.52** NS	1.192	**0.74** NS	0.234	**0.12** NS	5.140	**1.24** NS	2.05	2.75
Error	30	0.117		1.618		2.020		4.152			

APPENDIX – VI: Analysis of variance for yield attribute character's of onion

Variation due to	D. F.	fresh weight of bulb (g)		Diameter of bulb (cm)		Length of bulb (cm)		Table value of F at 5%	Table value of F at 1%
		MSS	Variance Ratio (F_{cal})	MSS	Variance Ratio (F_{cal})	MSS	Variance Ratio (F_{cal})		
Replication	2	18.863	**0.70**	0.130	**1.52**	0.027	**0.41**		
Treatments	15	199.237	**7.34**	0.958	**11.21**	0.694	**10.56**		
Sulphur levels (S)	3	579.090	**21.34****	2.059	**24.09****	1.880	**28.60****	2.92	4.51
Zinc levels (Zn)	3	357.772	**13.18****	2.128	**24.89****	1.403	**21.35****	2.92	4.51
S x Zn	9	19.774	**0.73** NS	0.202	**2.36***	0.062	**0.95** NS	2.05	2.75
Error	30	27.137		0.085		0.066			

APPENDIX - VII : Analysis of variance for bulb yield of onion

Variation due to	D. F.	Bulb yield (kg $plot^{-1}$)		Bulb yield (q ha^{-1})		dry weight of bulb/100g fresh weight		Table value of F at 5%	Table value of F at 1%
		MSS	Variance Ratio (F_{cal})	MSS	Variance Ratio (F_{cal})	MSS	Variance Ratio (F_{cal})		
Replication	2	1.256	**1.39**	492.8	**1.39**	0.147	**1.10**		
Treatments	15	4.733	**5.25**	1863.3	**5.26**	1.332	**9.99**		
Sulphur levels (S)	3	12.128**	**13.46****	4779.9**	**13.49****	3.355	**25.14****	2.92	4.51
Boron levels (B)	3	10.422**	**11.57****	4097.5**	**11.57****	2.665	**19.98****	2.92	4.51
S x B	9	0.372	**0.41** NS	146.3	**0.41** NS	0.214	**1.60** NS	2.05	2.75
Error	30	0.901		354.3		0.133			

VITA

PRIYANKA GURJAR, the author of this thesis was born on 5th September 1995, at Baijal Kothi Cantoment Road Morar, Gwalior (Madhya Pradesh). She passed his high school examination from St. Paul's School Morar, Gwalior (M.P.) with First division (60%) in the year 2010 and passed higher Secondary Examination in agriculture science, Excellence School No.1 Morar, Gwalior (M.P.) with First division (77%) in the year 2012.

In 2012, she joined the RVSKVV, College of Agriculture Gwalior (M.P.) and fruitfully obtained Bachelor Degree of Agriculture in the year2016 with an OGPA of 7.8 out of 10 point scale.Theshe joined M.Sc. (Ag.) course in 2016-17 in his beloved subject Horticulture at College of Agriculture, Gwalior (RVSKVV) for specialization of Masters Degree and passed in 2018 with first division with an OGPA of 7.41 out of 10 point scale. During master degree programme she has chosen are search problem on *"Effect of sulphur* and boron on growth and yield of onion (*Allium cepa* L.)*"* for thesis work which has been duly accomplished by him in M.Sc. in 2017-18.

.

Now she is going to complete her M.Sc. (Ag) degree program prerequisite after submission of this thesis.

Place: GWALIOR

Date: 18-05-2018 **(PRIYANKA GURJAR)**