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Research Article

RESPONSE OF GARLIC TO SULPHUR AND BORON APPLICATION IN TERMS OF YIELD AND YIELD ATTRIBUTES

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Abstract- Garlic (*Allium sativum* L.) is an important bulb crop next to onion. It is one of the most important spice crops in India. Present Experiment was laid out at college of agriculture, Gwalior during the winter season of 2015-16 & 2016-17. The experimental was laid out in Randomized Block Design with three replications and 16 number of four levels of Sulphur (0, 30, 45 & 60 kg/ha) and four levels of boron (0, 2, 3 & 4 kg/ha). Based on two years mean data; it is alluded that amongst the sulphur and boron levels raised all the above parameters up to maximum extent. For the sake of recommendation to the garlic growers in Gird region; B_3 boron level may be recommended with S_3sulphur level.

Key words- Sulphur, Boron, Garlic, Growth and yield

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Introduction

Garlic (*Allium sativum*L.) is an important bulb crop next to onion. It is one of the most important spice crops in India. Garlic is a bulbiferous crop belonging to the family Alliaceous. Garlic is native to southern Europe and western Asia (Etoh and Simon, 2002)[1]. It is the second most widely cultivated crop in the family after onion (*Allium cepa*) and contributes 14% of the world area and 5% of production.

The cloves of garlic bulb are used in flavoring of various vegetarian and non-vegetarian dishes. The significance of this spice is increasing owing to its wide range of medicinal properties. India ranks second in the world in respect of area and production. From India, large amount of dehydrated garlic products is exported to Japan, UK, Italy, Turkey, Germany and France. Garlic is important horticultural crop grown worldwide for culinary and medicinal purpose. India is a major garlic producing country with 1252 thousand tones production from 231-thousand-hectare area having 5.4t/ha productivity followed by China which has productivity of 23.53 t/ha. Among the major garlic growing states, Madhya Pradesh ranks first in area (60 thousand hectare) and production (270 thousand tones) with productivity of 4.5t/ha (NHB - 2014) [2].

The yield is very low as compared to the world average yield of 9.67 t ha^{-1} (FAO, 2002) [3]. Successful commercial cultivation of this crop depends up on many factors such as climate, soil fertility, irrigation, fertilizer management; spacing, growing season etc.The yield of garlic is quite low because of old and low yielded variety, improper or no use of nutrient and due to continuous depletion of macro and micro nutrients from soil.

Sulphur plays an important role in plant's growth and development. It is involved in the synthesis of amino acids like cystine, cysteine, methionine etc. It is also responsible for characteristic taste and smell of garlic like onion and mustard (Tisdale *et al*., 1985) [4].

Boron is one of the most widely applied micro-nutrient although it is required in very small quantity. It has different role in plant metabolic activities. Cell division, nitrogen and carbohydrates metabolism and water relation in plants are controlled by boron. Sugar translocation within the plant body is controlled by boron. In deficient condition of boron, growing plants become dead and ultimately the lateral shoots, buds and flowers dies. Chlorosis, thickening and curling of leaves are also observed. Boron also found to increase bulb yield up to 1kg B/ha (Francois, 1991) [5].

Most of the researches on nutrition of garlic limit the recommendation for major nutrients like N, P, and K, but micro-nutrients also play a vital role in deciding the growth and development of plants. Keeping the above facts in view, an experiment is to be conducted in experimental field of Department of Horticulture, College of Agriculture, Gwalior (M.P.) with the following objective to response of application of sulphur and boron in terms of yield and yield attributes.

Material and Method

Present Experiment was laid out at college of agriculture, Gwalior during the winter season of 2015-16 & 2016-17. Gwalior region receives mean annual rainfall about 751 mm. The monsoon starts in the month of June and often remains active up to September. The experimental was laid out in Randomized Block Design with three replications and 16 number of four levels of sulphur (0,30,45 & 60 kg/ha) and four levels of boron (0, 2, 3 & 4 kg/ha). Recommended dose of fertilizer; i.e. NPK @ 100:50:50 kg/ha was applied in the in all treatment. Basal application of fertilizers, full dose of phosphorus, potassium and ½ dose of nitrogen were applied in marked plots respectively. The transplanting time of seedlings was 10th October, 2015 and 12-10-2016. In the cultural operation, two weeding followed by hoeing were done manually after 30 and 45 days of transplanting. To protect the crop from insects and diseases spray of imidaclorprid 17% SL @ 250ml/ha and Carbandazim @ 1 kga.i./ha were done; respectively. Harvesting was done on 03 February 2016 and 07 February 2017 when 70% of the leaves senesced or fell over gently pulling up individual plants by hand.

Results and Discussion

The factors which are directly responsible for ultimate production *viz*. fresh weight

of bulb, dry weight of bulb, bulb length, bulb diameter, and bulbing ratio were augmented almost significantly due to suitable levels of sulphur and boron.

Fresh weight of bulb (g)

The data pertaining to fresh weight of bulb are presented in [Table-1&1.1]. This parameter was influenced significantly due to boron and sulphur levels as well as their interaction.

Boron level (B):

The B_3 (46.72 g) produced significantly higher fresh weight of bulb; which was at par with B_2 (45.93 g) over rest of the levels. The significantly lowest fresh weight of bulb was produced by B_0 (40.75 g).

Sulphur level (S):

S_3 (46.89 g) performed the best producing significantly higher fresh weight of bulb (46.89 g) over the other levels. However, the second-best level was S_2 (44.93 g). The significantly lowest fresh weight of bulb was noted in S_0 (42.11 g).

Interaction (B*S):

The maximum fresh weight of bulb was noticed under interaction of B_3 with S_3 (48.79 g) over rest of the interactions; while minimum value was noticed under interaction of B_0 with S_0 (38.72 g).

Dry weight of bulb (g)

The data pertaining to dry weight of bulb are presented in [Table-1&1.1]. This parameter was influenced significantly due to boron and sulphur levels as well as their interaction.

Boron level (B):

The B_3 (17.53 g) produced higher dry weight of bulb; which was at par with B_2 (17.31 g) over rest of the levels. The significantly lowest dry weight of bulb was produced by B_0 (14.55 g).

Sulphur level (S):

S_3 (17.70 g) produced significantly higher dry weight of bulb over other levels. However, the second-best level was S_2 (16.65 g). The significantly lowest dry weight of bulb was noted in S_0 (14.90 g).

Interaction (B*S):

The maximum dry weight of bulb was noticed under interaction of B_3 with S_3 (18.87 g) over rest of the interactions; while significantly minimum value was noticed under interaction of B_0 with S_0 (12.32 g).

Bulb length (cm)

The data pertaining to bulb length are presented in [Table-1&1.1]. This parameter was influenced significantly due to boron and sulphur levels as well as their interaction.

Table-1 *Response of Garlic to Sulphur and Boronin terms of yield attributes - I*

Treatment	Fresh weight of bulb (g)			Dry weight of bulb (g)			Bulb length (cm)			Bulb diameter (cm)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
B0	40.68	40.82	40.75	14.44	14.66	14.55	3.38	3.49	3.43	3.56	3.65	3.60
B1	44.15	44.29	44.22	15.80	16.02	15.91	3.83	3.94	3.89	4.02	4.11	4.07
B2	45.86	46.00	45.93	17.20	17.42	17.31	4.04	4.15	4.09	4.45	4.54	4.50
B3	46.65	46.79	46.72	17.42	17.64	17.53	4.16	4.27	4.22	4.53	4.62	4.57
SEm	0.60	0.60	0.43	0.39	0.39	0.27	0.17	0.17	0.12	0.13	0.13	0.09
CD	1.74	1.74	1.20	1.11	1.11	0.77	0.48	0.48	0.33	0.38	0.38	0.27
S0	42.04	42.18	42.11	14.79	15.01	14.90	3.44	3.55	3.49	3.64	3.73	3.69
S1	43.62	43.76	43.69	15.93	16.15	16.04	3.77	3.88	3.83	4.00	4.09	4.05
S2	44.86	45.00	44.93	16.54	16.76	16.65	4.01	4.12	4.07	4.34	4.43	4.38
S3	46.82	46.96	46.89	17.59	17.81	17.70	4.19	4.30	4.24	4.57	4.66	4.62
SEm	0.60	0.60	0.43	0.39	0.39	0.27	0.17	0.17	0.12	0.13	0.13	0.09
CD	1.74	1.74	1.20	1.11	1.11	0.77	0.48	0.48	0.33	0.38	0.38	0.27
B*S												
SEm	1.20	1.20	0.85	0.77	0.77	0.55	0.33	0.33	0.24	0.27	0.27	0.19
CD	NS	NS	2.41	NS	NS	1.54	NS	NS	0.67	NS	NS	0.53

Table-1.1 *Response of Garlic to Interaction (S*B) in terms of yield attributes – I (Pooled)*

Treatment	Yield attributes – I															
	Fresh weight of bulb (g)				Dry weight of bulb (g)				Bulb length (cm)				Bulb diameter (cm)			
	B0	B1	B2	B3	B0	B1	B2	B3	B0	B1	B2	B3	B0	B1	B2	B3
S0	38.72	40.85	44.18	44.70	12.32	14.97	16.02	16.30	2.70	3.59	3.72	3.97	3.08	3.58	3.99	4.10
S1	38.72	44.18	45.25	46.59	14.59	15.01	17.26	17.30	3.46	3.71	4.03	4.11	3.55	3.83	4.39	4.44
S2	40.85	45.25	46.81	46.81	14.98	16.33	17.64	17.66	3.71	4.00	4.27	4.28	3.76	4.33	4.66	4.79
S3	44.70	46.59	47.48	48.79	16.30	17.33	18.31	18.87	3.86	4.25	4.35	4.51	4.03	4.54	4.94	4.97
SE(m)	0.85				0.55				0.24				0.19			
CD	2.41				1.54				0.67				0.53			

Boron level (B):

The B_3 (4.22 cm) registered higher bulb length; which was at par with B_2 (4.09 cm) over rest of the levels. The significantly lowest bulb length was produced by B_0 (3.43 cm).

Sulphur level (S):

S_3 (4.24 cm) produced higher bulb length over other levels. However, the second best level was S_2 (4.07 cm). The significantly lowest bulb length was noted in S_0 (3.49 cm).

Interaction (B*S):

The maximum bulb length was noticed under interaction of B_3 with S_3 (4.51 cm) over rest of the interactions; while significantly minimum value was noticed under interaction of B_0 with S_0 (2.70 cm).

Bulb diameter (cm)

The data pertaining to bulb diameter are presented in [Table-1&1.1]. This parameter was influenced significantly due to boron and sulphur levels as well as their interaction.

Boron level (B):
The higher bulb diameter was recorded under B_3 (4.57 cm); which was at par with B_2 (4.50 cm) over rest of the levels. The significantly lowest bulb diameter was produced by B_0 (3.60 cm).

Sulphur level (S):
S_3 (4.62 cm) produced higher bulb diameter; which was at par with S_2 (4.38 cm) over other levels. The significantly lowest bulb diameter was noted in S_0 (3.69 cm).

Interaction (B*S):
The maximum bulb diameter was noticed under interaction of B_3 with S_3 (4.97 cm) over rest of the interactions; while minimum value was noticed under interaction of B_0 with S_0 (3.08 cm).

Bulbing ratio
The data pertaining to bulbing ratio are presented in [Table-2 &2.1]. This parameter was influenced significantly due to boron and sulphur levels as well as their interaction.

Table-2 *Response of Garlic to Sulphur and Boronin terms of Bulb yield (kg/plot), Bulb Yield (t/ha) and Bulbing ratio*

Treatment	Bulb yield (kg/plot)			Bulb yield (t/ha)			Bulbing ratio		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
B0	7.03	7.06	7.05	12.99	13.04	13.01	15.21	15.10	15.16
B1	7.86	7.89	7.88	14.52	14.57	14.55	15.13	15.04	15.09
B2	8.29	8.32	8.30	15.31	15.36	15.34	14.70	14.62	14.66
B3	8.44	8.46	8.45	15.58	15.63	15.61	15.08	15.00	15.04
SEm	0.19	0.19	0.13	0.35	0.35	0.24	0.66	0.64	0.46
CD	0.54	0.54	0.37	1.00	1.00	0.69	NS	NS	1.30
S0	7.39	7.42	7.40	13.65	13.70	13.67	15.73	15.61	15.67
S1	7.66	7.69	7.68	14.15	14.20	14.18	14.67	14.59	14.63
S2	8.14	8.17	8.16	15.04	15.09	15.07	14.83	14.75	14.79
S3	8.43	8.45	8.44	15.56	15.61	15.58	14.89	14.81	14.85
SEm	0.19	0.19	0.13	0.35	0.35	0.24	0.66	0.64	0.46
CD	0.54	0.54	0.37	1.00	1.00	0.69	NS	NS	1.30
B*S									
SEm	0.37	0.37	0.26	0.69	0.69	0.49	1.31	1.28	0.92
CD	NS	NS	0.75	NS	NS	1.38	NS	NS	2.59

Table-2.1 *Response of Garlic to Interaction (S*B)in terms of Bulb yield (kg/plot), Bulb Yield (t/ha) and Bulbing ratio (Pooled)*

Treatment	Bulb yield (kg/plot)				Bulb yield (t/ha)				Bulbing ratio			
	B0	B1	B2	B3	B0	B1	B2	B3	B0	B1	B2	B3
S0	6.44	7.54	7.69	7.94	11.89	13.92	14.20	14.67	16.77	16.01	14.63	15.28
S1	6.44	7.69	8.28	8.31	11.89	14.20	15.29	15.34	14.46	14.80	14.71	14.54
S2	7.54	7.95	8.53	8.61	13.92	14.68	15.76	15.90	14.96	14.49	14.70	15.02
S3	7.77	8.33	8.72	8.94	14.35	15.38	16.10	16.51	14.44	15.04	14.60	15.33
SE(m)	0.26				0.49				0.92			
CD	0.75				1.38				2.59			

Boron level (B):
The higher bulbing ratio was recorded under B_0 (15.16); while lowest value was registered by B_2 (14.66).

Sulphur level (S):
S_0 (15.67) produced higher bulbing ratio; while lowest value was noted under S_1 (14.63).

Interaction (B*S):
The maximum bulbing ratio was noticed under interaction of B_0 with S_0 (16.77); while minimum value was noticed under interaction of B_0 with S_3 (14.44).
The S_3 and B_3 levels recorded significantly higher yield attributing parameters over rest of the levels. The higher yield attributes from these levels may be due to increased morphological parameters as a result of all favorable situations might have resulted in greater accumulation of carbohydrates, proteins and their translocation from source to the sink (reproductive organs); which increased the higher yield attributing parameters. These results confirm the findings of Smriti*et al*. (2002) [6], Paul et al. (2007)[7], Abedin *et al*. (2012)[8], Mishu*et al*. (2013)[9] and Mondal *et al*. (2016)[10].
Each plant passes through the vegetative as well as reproductive phases of growth to complete its life cycle. Yield can be considered to be the final expression of the physiological and metabolic activities of plants and is governed by various factors. These yield attributing factors have direct bearing on plant productivity and for increasing the yield.
The bulb yield was found significantly higher in case of S_3 and B_3 levels and proved to be superior to the remaining levels. The trend of increases in bulb yield obtained due to these treatments was exactly in accordance with the similar increases in the yield attributing characters as well as increased vegetative growth.
The bulbing ratio was found to be higher with the B_0 and S_0 levels. When higher levels were applied, the bulbing ratio was further lowered.

Bulb yield (t/ha)
The data pertaining to bulb yield (t/ha) are presented in [Table-2&2.1]. This parameter was influenced significantly due to boron and sulphur levels as well as their interaction.

Boron level (B):
The higher bulb yield was registered under B_3 (15.61 t/ha); which was at par with B_2 (15.36 t/ha) over rest of the levels. The significantly lowest value was registered by B_0 (13.01 t/ha).

Sulphur level (S):
S_3 (15.58 t/ha) produced higher bulb yield; which was at par with S_2 (15.07 t/ha) over rest of the levels. However, the lowest value was noted in S_0 (13.67 t/ha).

Interaction (B*S):
The maximum bulb yield was noticed under interaction of B_3 with S_3 (16.51 t/ha) over rest of the interactions; while minimum value was noticed under interaction of B_0 with S_0 (6.44 t/ha).
The yield advantage of different treatments was due to better growth and development. Thus, higher photosynthate accumulation in the cloves for higher leaves/plant would ensure higher cloves/bulb, large bulb diameter, and higher bulb weight. Moreover, applied boron in combination with sulphur undoubtedly increased the yield indicating that the soil was deficient in those nutrients. The beneficial effect of sulphur and boron in single as well as in combination were also

reported by Smriti *et al*. (2002)[6], Paul et al. (2007)[7], Nasreen *et al*. (2009)[11], Abedin *et al*. (2012)[8],Manna *et al*. (2014)[12] and Mondal *et al*. (2016)[10].

Conclusion

Based on two years mean data; it is alluded that amongst the sulphur and boron levels raised all the above parameters upto maximum extent. For the sake of recommendation to the garlic growers in Gird region; B_3 boron level may be recommended with S_3sulphur level.

Application of Research:

Present study is very useful to find out the new ways in micro nutrient requirement of garlic crop. Study will used as ready reference for further research in the field of garlic nutrition and quality aspects.

Research Category: Horticulture, Vegetable Science

Abbreviations:

a.i.: Active ingredient
B: Boron
Kg: Kilogram
Ha: Hectare
S: Sulphur

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Author Contributions:

1. C.V. Singh: Carried out research work, data collection and paper writing
2. Prashant Gupta: Chairman of research committee, assisted in carrying research work.
3. B.S. Kasana: Technical guidance during research work and paper writing.

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