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Influence of sulphur, zinc and boron on growth, yield and quality of onion

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Abstract
Field experiments were carried out to study the response of onion to different levels of sulphur (0, 15, 30kg/ha), zinc (0, 2, 4 kg/ha) and boron (0, 1, 2 kg/ha) along with recommended dose of fertilizer. totally 27 treatment combinations were made, laid out in factorial randomized block design with two replications, conducted at Olericulture unit of Kittur Rani Channamma College of horticulture, Belgaum district (Karnataka), during *kharif*, 2016. Results revealed that application of sulphur (30 kg/ha) significantly increased the plant height (62.75cm), number of leaves (9.75), neck thickness (2.49cm) when applied with zinc (4kg/ha) and boron (2kg/ha). bulb yield (31.25t/ha), Total soluble solids (13.08 ^{0}B), sulphur content in bulbs(0.59%), polar diameter (6.05cm), equatorial diameter(6.33cm) fresh weight of bulb(107.07gm), dry weight of bulb (33.50gm) when applied with zinc (4kg/ha) and boron (2kg/ha). And minimum rotting loss (5.07%), sprouting loss (3.79%), physiological loss in weight (10.24%) are found significant with application of sulphur (30 kg/ha), zinc (4kg/ha) and boron (2kg/ha). The study indicated that application of sulphur (30 kg/ha), zinc (4kg/ha) and boron (2kg/ha) with recommended dose of fertilizers was found to be the most appropriate combination for getting higher yield compared to other treatments.

Keywords: Onion, sulphur, zinc, boron interaction, vegetative growth

Introduction
Onion (*Allium cepa* L.) belongs to the family Alliaceae, is one of the most important monocotyledonous, cross-pollinated and cool season vegetable crop. Onion is popularly known as Piaz in Hindi and Ullagaddi/Irulli in Kannada. Onion has its own distinctive flavor, used in soups, meat dishes, salads and sandwiches and is cooked alone as a vegetable. It`s pungency is due to the presence of volatile oil "Allyl propyl disulphide" (Khan *et al*., 2007) [7]. Generally 100 g of edible bulb of onion contains 86.6 g of moisture, 11.0 g of carbohydrates, 1.2 g of protein, 0.6 g of fibre and 0.4 g of minerals. It also contains calcium (180mg), phosphorous (50 mg), iron (0.7mg), thiamine and nicotinic acid (0.4mg). The origin of onion is thought to be Iran, Pakistan and the mountainous regions to north of these countries. The leading onion growing countries of the world are the Netherland, Korea, Israel, Japan, Turkey, Syria, Egypt, USA, Lebanon and India (Rashid, 2010) [11]. Onion requires sufficient amount of plant nutrients and responds very well to the added nutrients (Alam *et al.*, 20l0) [1]. Sulphur is recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium in crops. Sulphur deficiency in Indian soil adversely affect crop production besides recommended dose of NPK fertilizers application (Surendra Singh, 2008) [13]. It is essential for the synthesis of amino acids like cystine, cysteine and methionine, a component of vitamin 'A' and activates certain enzyme systems in plants. Continuous removal of S from soils through plant uptake has led to widespread S deficiency all over the world (Zaman *et al.*, 2011) [15]. Zinc plays vital role in carbohydrate metabolism. It is involved in diverse range of enzyme system. Zinc is taken up by plants as Zn^{+2}. The functional role of Zn includes auxin metabolism, influence on the activities of dehydrogenase and carbonic anhydrate enzymes, synthesis of cytochrome and stabilization or ribosomal fractions (Tisdale *et al.,* 1984) [14]. Boron is an essential micronutrient required for normal plant growth and development. It performs wide range of functions in onion plant. It is very sensitive element and plants differ widely in their requirements but the ranges of deficiency and toxicity are narrow. It maintains balance between sugar and starch in plant body (Ali, 2013) [2].

Information on effect of combined application of S, Zn and B on yield, quality and uptake of nutrients in onion is rather limited. Therefore, the present study was initialized to study the effect of S, Zn and B application on yield, quality and uptake of nutrients by onion in Northern dry zone of Karnataka.

Material and Methods

The field experiment was conducted at Kittur Rani Channamma College of Horticulture, Arabhavi, Belgaum district of Karnataka is located in northern zone of Karnataka state at 16^0 15' latitude, 74^0 45'E longitude and at altitude of 612.03 meters above the mean sea level. The experiment was laid out in a factorial randomized block design with two replications and 27 treatments using three levels of S (0, 15, 30kg/ha), three levels of Zn (0, 2, 4 kg/ha) and three levels of B (0, 1, 2kg/ha) along with the recommended dose of fertilzers.

Onion seedlings of 30 days old were transplanted with spacing of 15x10 cm. Fertilizers were applied to soil on the day of transplanting as per the treatment details. Sulfur, zinc and boron were supplied as per the treatment requirements through elemental sulphur, Zinc sulphate and Borax fertilizers respectively. All the recommended agronomic practices and crop husbandry were followed to raise a good crop. Five plants were selected randomly from each net plot to record the observation namely, plant height, number of leaves per plant, leaf area, neck thickness. The data recorded on different parameter during crop growth stages of investigation were statically analyzed as per the statistical methods described by Sundararaj *et al*. (1972) [12].

Results and Discussion

Application of different levels of nutrients showed significant difference among the treatments on vegetative growth. The plant height at 75 days after transplanting as influenced by application of different levels of sulphur had significant effect on plant height. Significantly higher plant height was recorded in S_2 (60.95 cm) followed by S_1 (58.01 cm) and significantly lowest was observed in S_0 (55.72 cm). Significantly higher plant height recorded in Z_2 (59.77 cm) followed by Z_1 (58.17 cm) and difference between them being significant while Z_0 (56.73 cm) had least plant height. Different levels of boron had significant effect on plant height at 75 days after transplanting. Significantly higher plant height was noticed with B_2 (59.38 cm) which was on par with B_1 (58.15 cm) and the lowest was recorded in B_0 (57.14 cm).The interaction effect of sulphur and zinc differed significantly with respect to plant height at 75 days after transplanting. Significantly higher plant height was recorded in S_2Z_2 (62.30 cm) which was on par with S_2Z_1 (61.62 cm), S_1Z_2 (60.38 cm) and the lowest was observed in S_0Z_0 (54.92 cm) which is at par with S_0Z_1 (55.62 cm). Significantly higher plant height was noticed in S_2B_2 (62.68 cm) which was on par with S_2B_1 (60.72 cm) followed by S_2B_0, S_1B_2 and S_1B_1 recorded (59.45, 59.23 and 57.97 cm) which were on par with each other and the lowest was found in S_0B_0 (55.15 cm) which were on par with S_0B_1 (55.77 cm), S_0B_2 (56.23 cm) and S_1B_0 (56.82 cm). Significantly higher plant height was found in Z_2B_2 (60.67 cm) which was on par with Z_2B_1 (59.83 cm), Z_2B_0 (58.80 cm) and Z_1B_2 (59.23 cm) the lowest was in Z_0B_0 (55.65 cm) which were on par with Z_0B_1 (56.30 cm) and Z_1B_0 (56.97 cm). Significantly higher plant height was observed in $S_2Z_2B_2$ (63.05 cm) which were on par with $S_2Z_2B_1$, $S_2Z_2B_0$, $S_2Z_1B_2$ and $S_2Z_1B_1$ recorded (62.30, 61.85 62.75, and 61.80 cm respectively). Significantly lowest plant height was recorded in $S_0Z_0B_0$ (54.65 cm).

The data on number of leaves per plant as influenced by application of different levels of sulphur, zinc and boron and their interactions of SZ, SB, ZB and SZB at 60 days after transplanting are presented in Table 2 and 2a. Significantly higher number of leaves per plant was recorded in S_2 (9.18) followed by S_1 (8.64) and was lowest recorded in S_0 (8.17). Significantly higher number of leaves per plant was recorded in Z_2 (9.05) this was followed by Z_1 (8.67) and Z_0 was recorded the lowest number of leaves (8.28). Higher number of leaves per plant was noticed with B_2 (9.02) followed by B_1 (8.63) and lowest was noticed in B_0 (8.34). Significantly higher number of leaves per plant was recorded in S_2Z_2 (9.58) followed by S_2Z_1 (9.23) and S_1Z_2 (9.10) which were on par with each other and the lowest was recorded in S_0Z_0 (7.87). Significant differences due to interaction effect of sulphur and boron on number of leaves per plant at 60 days after transplanting. Significantly higher number of leaves per plant was recorded in S_2B_2 (9.55) followed by S_2B_1 (9.17) and the lowest was noticed in S_0B_0 (7.87). Significantly higher number of leaves per plant was found in Z_2B_2 (9.38) followed by Z_1B_2 (9.07) and Z_2B_1 (9.03) which were at par and the lowest was recorded in Z_0B_0 (7.97). interaction effect of sulphur, zinc and boron on number of leaves per plant at 60 days after transplanting was found to be significant. Significantly higher number of leaves was in $S_2Z_2B_2$ (9.75) which were on par with $S_2Z_2B_1$, $S_2Z_1B_2$ and $S_1Z_2B_2$ recorded (9.60, 9.70 and 9.60). Significantly lowest number of leaves was recorded in $S_0Z_0B_0$ (7.60).

The data on neck thickness due to application of different levels of sulphur, zinc and boron and their interactions of SZ, SB, ZB and SZB at 80 days after transplanting are presented in Table 3 and 3a.Significant differences were obtained due to different levels of sulphur with respect to neck thickness at 80 days after transplanting. Significantly maximum neck thickness was recorded in S_2 (1.97cm) followed by S_1 (163cm) and lowest was noticed in S_0 (1.33cm). Significant differences in neck thickness at 80 days after transplanting were observed due to application of different levels of zinc. Significantly maximum neck thickness was noticed in Z_2 (1.89cm) followed by Z_1 (1.64cm). Lowest neck thickness was recorded in Z_0 (1.40cm). Maximum neck thickness was noticed with B_2 (1.85cm) followed by B_1 (1.64cm) and they were at par. B_0 recorded the lowest (1.44cm). B_0 and B_1 were at par. Significantly maximum neck thickness was recorded in S_2Z_2 (2.23cm) which was on par with S_2Z_1 (1.95cm) followed by S_2Z_0 and S_1Z_1 recorded (1.73 and 1.62cm respectively) which were on par with each other and the lowest was noticed in S_0Z_0 (1.08cm) which is on par with S_0Z_1 (1.34cm). Significantly maximum neck thickness was observed in S_2B_2 (2.19cm) which was on par with S_2B_1 (1.97cm) followed by S_2B_0, S_1B_1 and S_1B_0 recorded (1.76, 1.62 and 1.43cm) which were on par with each other and the lowest was recorded in S_0B_0 (1.14 cm) which were on par with S_0B_1 (1.32cm). The interaction of zinc and boron differed significantly with respect to neck thickness at 80 days after transplanting. Significantly maximum neck thickness was in Z_2B_2 (2.12cm) followed by Z_2B_1 (1.87cm) and they were at par. Lowest was noticed in Z_0B_0 (1.21cm) followed by Z_0B_1 (1.40cm), Z_0B_2 (1.61cm) and they were at par. Neck thickness at 80 days after transplanting was differed significantly due to interaction effect of sulphur, zinc and boron. Significantly maximum neck thickness was recorded in $S_2Z_2B_2$ (2.49cm) followed by $S_2Z_2B_1$, $S_2Z_1B_2$, $S_2Z_2B_0$ and $S_2Z_1B_1$ recorded (2.20, 2.14, 2.01and 1.97cm respectively). Significantly minimum neck thickness was recorded in $S_0Z_0B_0$ (0.91cm).

The data on leaf area due to application of different levels of sulphur, zinc and boron and their interactions of SZ, SB, ZB and SZB are presented in Table 4 and 4a.Application of different levels of sulphur had significant effect on leaf area. Significantly higher leaf area was recorded in S_2 (176.12 cm^2). Lowest leaf area was observed in S_0 (124.84 cm^2). Significant differences in leaf area were observed due to application of different levels of zinc. Significantly higher leaf area was noticed in Z_2 (171.42 cm^2). Z_0 was recorded the lowest leaf area (124.24 cm^2). Different levels of boron had significant effect on leaf area. Higher leaf area was noticed with B_2 (169.33 cm^2) and lowest was observed in B_0 (130.00 cm^2). The interaction effect of sulphur and zinc differed significantly with respect to leaf area. Significantly higher leaf area was noticed in S_2Z_2 (201.79 cm^2) followed by S_2Z_1 (177.94 cm^2) and the lowest was found in S_0Z_0 (100.99 cm^2). The interaction effect of sulphur and boron differed significantly with respect to leaf area. Significantly higher leaf area was found in S_2B_2 (197.11 cm^2) followed by S_2B_1 (177.24 cm^2) and the lowest was recorded in S_0B_0 (112.50 cm^2).The interaction effect of boron and zinc differed significantly with respect to leaf area. Significantly higher leaf area was recorded in Z_2B_2 (189.62 cm^2) followed by Z_2B_1 (174.23 cm^2) and the lowest was noticed in Z_0B_0 (106.50 cm^2). Leaf area was found to be significant due to interaction effect of sulphur, zinc and boron. Significantly higher leaf area was noticed in $S_2Z_2B_2$ (208.68 cm^2) followed by $S_2Z_2B_1$ and $S_2Z_1B_2$ recorded (204.48 and 203.49 cm^2) which were found to be on par with each other. Significantly lowest leaf area was recorded in $S_0Z_0B_0$ (90.67 cm^2). The growth parameters *viz.*, plant height, number of leaves per plant, neck thickness and leaf area at various stages of crop growth as influenced by combined effect of zinc and boron is presented in Table 2. The interaction effect of zinc and boron was significant on all the growth parameters. The highest values of growth parameters was obtained from 4 kg zinc and 2 kg boron per hectare. Application of zinc and boron through soil or in combination had a beneficial effect on growth of onion. This may be due to zinc and boron play an essential role in plant growth through the biosynthesis of endogenous hormones which is responsible for promotion of plant growth and role in cell division, meristametic activity of plant tissue and expansions of cells. The results are similar to findings of Bhatt *et al*. (2004) [4], Patil *et al*. (2008) [9] and Hanch and Mendel, 2009. These results are in agreement with the findings of Anwer *et al.* (1998) [3], Kumar *et al.* (1998) [8], Gamili *et al*. (2000) And Ram and Katiyar, (2013) [10].

Table 1: Plant height at 75 days after transplanting as influenced by different levels of sulphur, zinc and boron and their interactions in onion.

	Plant height (cm) at 75 DAT			
	Sulphur levels (kg/ha)			
Zinc levels (kg/ha)	S_0	S_1	S_2	Mean
Z_0	54.92	56.35	58.93	56.73
Z_1	55.62	57.28	61.62	58.17
Z_2	56.62	60.38	62.30	59.77
Mean	55.72	58.01	60.95	
	SEm ±		CD at 5%	
S/Z	0.45		1.32	
S×Z	0.79		2.28	
Boron levels(kg/ha)				
B_0	55.15	56.82	59.45	57.14
B_1	55.77	57.97	60.72	58.15
B_2	56.23	59.23	62.68	59.38
Mean	55.72	58.01	60.95	
	SEm ±		CD at 5%	
B	0.45		1.32	
S×B	0.79		2.28	
	Zinc levels (kg/ha)			
Boron levels (kg/ha)	Z_0	Z_1	Z_2	Mean
B_0	55.65	56.97	58.80	57.14
B_1	56.30	58.32	59.83	58.15
B_2	58.25	59.23	60.67	59.38
Mean	56.73	58.17	59.77	
	SEm ±		CD at 5%	
Z×B	0.78		2.28	

S_0, S_1 and S_2 – 0, 15 and 30 kg/ha respectively B_0, B_1 and B_2 - 0, 1 and 2 kg/ha respectively Z_0, Z_1 and Z_2 - 0, 2 and 4 kg/ha respectively DAT- days after transplanting

Table 1a: Plant height at 75 days after transplanting as influenced by different levels of sulphur, zinc and boron and their interactions in Onion.

	Plant height (cm) at 75 DAT								
	Z_0			**Z_1**			**Z_2**		
Sulphur levels (kg/ha)	**B_0**	**B_1**	**B_2**	**B_0**	**B_1**	**B_2**	**B_0**	**B_1**	**B_2**
S_0	54.65	54.9	55.2	55	55.8	56.05	55.8	56.6	57.45
S_1	55.75	56	57.3	55.95	57.3	58.6	58.75	60.6	61.8
S_2	56.55	58	62.25	59.95	61.85	63.05	61.85	62.3	62.75
SEm ±	1.36								
CD at 5%	3.95								

S_0, S_1 and S_2 – 0, 15 and 30 kg/ha respectively B_0, B_1 and B_2 - 0, 1 and 2 kg/ha respectively
Z_0, Z_1 and Z_2 - 0, 2 and 4 kg/ha respectively DAT- days after transplanting

Table 2: Number of leaves per plant at 60 days after transplanting as influenced by different levels of sulphur, zinc and boron and their interactions in onion.

	Number of leaves 60 DAT			
	Sulphur levels (kg/ha)			
Zinc levels (kg/ha)	S_0	S_1	S_2	Mean
Z_0	7.87	8.23	8.73	8.28
Z_1	8.17	8.60	9.23	8.67
Z_2	8.47	9.10	9.58	9.05
Mean	8.17	8.64	9.18	
	SEm ±		CD at 5%	
S/Z	0.03		0.07	
S×Z	0.04		0.13	
Boron levels(kg/ha)				
B_0	7.87	8.33	8.83	8.34
B_1	8.17	8.57	9.17	8.63
B_2	8.47	9.03	9.55	9.02
Mean	8.17	8.64	9.18	
	SEm ±		CD at 5%	
B	0.03		0.07	
S×B	0.04		0.13	
	Zinc levels (kg/ha)			
Boron levels (kg/ha)	Z_0	Z_1	Z_2	Mean
B_0	7.97	8.33	8.73	8.34
B_1	8.27	8.60	9.03	8.63
B_2	8.60	9.07	9.38	9.02
Mean	8.28	8.67	9.05	
	SEm ±		CD at 5%	
Z×B	0.04		0.13	

S_0, S_1 and S_2 – 0, 15 and 30 kg/ha respectively B_0, B_1 and B_2 - 0, 1 and 2 kg/ha respectively Z_0, Z_1 and Z_2 - 0, 2 and 4 kg/ha respectively DAT- days after transplanting

Table 2a: Number of leaves per plant at 60 days after transplanting as influenced by different levels of sulphur, zinc and boron and their interactions in onion.

	Number of leaves 60 DAT								
	Z_0			**Z_1**			**Z_2**		
Sulphur levels (kg/ha)	B_0	B_1	B_2	B_0	B_1	B_2	B_0	B_1	B_2
S_0	7.60	7.90	8.10	7.90	8.10	8.50	8.10	8.50	8.80
S_1	8.00	8.20	8.50	8.30	8.50	9.00	8.70	9.00	9.60
S_2	8.30	8.70	9.20	8.80	9.20	9.70	9.40	9.60	9.75
SEm ±	0.08								
CD at 5%	0.22								

S_0, S_1 and S_2 – 0, 15 and 30 kg/ha respectively B_0, B_1 and B_2 - 0, 1 and 2 kg/ha respectively
Z_0, Z_1 and Z_2 - 0, 2 and 4 kg/ha respectively DAT- days after transplanting

Table 3: Neck thickness at 80 days after transplanting as influenced by different levels of sulphur, zinc and boron and their interactions in onion.

	Neck thickness (cm) at 80 DAT			
	Sulphur levels (kg/ha)			
Zinc levels (kg/ha)	**S_0**	**S_1**	**S_2**	**Mean**
Z_0	1.08	1.40	1.73	1.40
Z_1	1.34	1.62	1.95	1.64
Z_2	1.56	1.87	2.23	1.89
Mean	1.33	1.63	1.97	
	SEm ±		CD at 5%	
S/Z	0.08		0.24	
S×Z	0.14		0.41	
Boron levels(kg/ha)				
B_0	1.14	1.42	1.76	1.44
B_1	1.32	1.62	1.97	1.64
B_2	1.52	1.84	2.19	1.85
Mean	1.33	1.63	1.97	
	SEm ±		CD at 5%	
B	0.08		0.24	
S×B	0.14		0.41	
	Zinc levels (kg/ha)			
Boron levels (kg/ha)	Z_0	Z_1	Z_2	Mean
B_0	1.21	1.43	1.67	1.44
B_1	1.40	1.65	1.87	1.64
B_2	1.61	1. 83	2.12	1.85

Mean	1.40	1.64	1.89	
	SEm ±		CD at 5%	
Z×B	0.14		0.41	

S_0, S_1 and S_2 – 0, 15 and 30 kg/ha respectively B_0, B_1 and B_2 - 0, 1 and 2 kg/ha respectively Z_0, Z_1 and Z_2 - 0, 2 and 4 kg/ha respectively DAT- days after transplanting

Table 3a: Neck thickness at 80 days after transplanting as influenced by different levels of sulphur, zinc and boron and their interactions in onion.

	Neck thickness (cm) at 80 DAT								
	Z_0			**Z_1**			**Z_2**		
Sulphur levels (kg/ha)	**B_0**	**B_1**	**B_2**	**B_0**	**B_1**	**B_2**	**B_0**	**B_1**	**B_2**
S_0	0.91	1.05	1.27	1.14	1.34	1.54	1.36	1.57	1.76
S_1	1.20	1.40	1.60	1.42	1.63	1.82	1.66	1.83	2.12
S_2	1.52	1.73	1.95	1.74	1.97	2.14	2.01	2.20	2.49
SEm ±	0.24								
CD at 5%	0.71								

S_0, S_1 and S_2 – 0, 15 and 30 kg/ha respectively B_0, B_1 and B_2 - 0, 1 and 2 kg/ha respectively
Z_0, Z_1 and Z_2 - 0, 2 and 4 kg/ha respectively DAT- days after transplanting

Table 4: Leaf area at 105 day after transplanting as influenced by different levels of sulphur, zinc and boron and their interactions in onion.

	Leaf area (cm^2) at 105 DAT			
	Sulphur levels (kg/ha)			
Zinc levels (kg/ha)	**S_0**	**S_1**	**S_2**	**Mean**
Z_0	100.99	123.10	148.63	124.24
Z_1	129.49	149.43	177.94	152.28
Z_2	144.03	168.45	201.79	171.42
Mean	124.84	146.99	176.12	
	SEm ±		CD at 5%	
S/Z	0.88		2.56	
S×Z	1.52		4.43	
Boron levels(kg/ha)				
B_0	112.50	123.51	154.01	130.00
B_1	121.00	147.60	177.24	148.61
B_2	141.01	169.87	197.11	169.33
Mean	124.84	146.99	176.12	
	SEm ±		CD at 5%	
B	0.88		2.56	
S×B	1.52		4.43	
	Zinc levels (kg/ha)			
Boron levels (kg/ha)	Z_0	Z_1	Z_2	Mean
B_0	106.50	133.09	150.42	130.00
B_1	121.38	150.23	174.s23	148.61
B_2	144.84	173.53	189.62	169.33
Mean	124.24	152.28	171.42	
	SEm ±		CD at 5%	
Z×B	1.52		4.43	

S_0, S_1 and S_2 – 0, 15 and 30 kg/ha respectively B_0, B_1 and B_2 - 0, 1 and 2 kg/ha respectively Z_0, Z_1 and Z_2 - 0, 2 and 4 kg/ha respectively DAT- days after transplanting

Table 4a: Leaf area at 105 day after transplanting as influenced by different levels of sulphur, zinc and boron and their interactions in onion.

	Leaf area (cm^2) at 105 DAT								
	Z_0			**Z_1**			**Z_2**		
Sulphur levels (kg/ha)	**B_0**	**B_1**	**B_2**	**B_0**	**B_1**	**B_2**	**B_0**	**B_1**	**B_2**
S_0	90.67	100.29	112.02	130.48	118.10	139.89	116.34	144.62	171.13
S_1	104.06	121.91	143.33	123.75	147.32	177.21	142.71	173.58	189.06
S_2	124.76	141.96	179.17	145.05	185.27	203.49	192.21	204.48	208.68
SEm ±	2.24								
CD at 5%	7.67								

S_0, S_1 and S_2 – 0, 15 and 30 kg/ha respectively B_0, B_1 and B_2 - 0, 1 and 2 kg/ha respectively
Z_0, Z_1 and Z_2 - 0, 2 and 4 kg/ha respectively DAT- days after transplanting

Conclusion

The results of the present investigation infer that soil application of sulphur (30 kg/ha), zinc (4kg /ha) and boron (2 kg/ha) along with recommended dose of fertilizer was found superior for not only increasing the bulb yield but also improved storage quality and economics of onion bulb. The results obtained in the present investigation are based on one year experiment and needs more trials for confirmation for final recommendations.

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