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Effect of Zinc and Boron on Growth, Yield and Quality of Onion (*Allium cepa* L.) cv. Agrifound Dark Red

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A B S T R A C T

Studies on effect of zinc and boron on growth, yield and quality of onion cv. Agrifound Dark Red was carried out with nine treatment (zinc viz., 0, 25 and 50 kg/ha and boron viz., 0, 2.5 and 5 kg/ha) combinations. Results were significant in most of the parameters. The highest plant height (57.47 cm), number of leaves (12.37), neck thickness (1.68 cm), bulb diameter (6.83 cm), bulb weight (110.80 g), yield plot^{-1} (5.32 kg), yield hectare^{-1} (236.59 q), dry weight of bulb (14.30 g), total soluble solids (TSS) (13.98%), Zn content in leaves (41.27 ppm) and bulbs (55.33 ppm), B content in leaves (13.87 ppm) and bulbs (14.43 ppm), N (1.49%), P (0.58%) and K (1.77%) content in leaves and N (1.60%), P (0.47%) and K (1.85%) content in bulbs were maximum in treatment combination of Zn 25 kg + B 5 kg ha^{-1}, while treatment combination of Zn 50 kg + B 5 kg ha^{-1} showed maximum sulphur content in leaves (2196.7 ppm) and bulbs (2344 ppm). The results clearly indicated that soil application of Zn 25 kg + B 5 kg ha^{-1} significantly improved the growth, yield and quality of onion compared to other treatment combinations and control and also found economically best with benefit cost ratio 1: 4.3.

Introduction

The onion (*Allium cepa* L.) belonging to the family Alliaceae is one of the most important bulbous crop of the world and the most important commercial crop grown all over the country for both spice as well as for vegetable purpose. It has medicinal and diuretic properties, relieves heat sensation, hysterical faintness, insect bites and also heart stimulation. Through many experiments conducted on onion, it has been realized that the better growth and quality and higher yield of onion can be obtained with the adequate and balanced application of both macronutrients and micronutrients under suitable agro climatic condition.

Micronutrients play an active role in the plant metabolic process from cell wall development to respiration, photosynthesis, chlorophyll formation, enzymes activity, nitrogen fixation etc. Micronutrients work as a co- enzyme for a large number of enzymes. It also plays an essential role in improving yield and quality and highly required for better plant growth and yield of many crops (Alam *et al.*, 2010). Soil application of micronutrients during crop growth (onion) was successfully used for correcting their deficits and improving the mineral status of plants as well as increasing the crop yield and quality (Jawaharlal *et al.*, 1986; Thakare *et al.*, 2007; Ali, 2013). The onion, like any other crops not only needs macronutrients but also micronutrients in adequate and balanced amounts (Ballabh *et al.*, 2013).

It was reported that North Eastern region of India is deficient of zinc whose deficiency causes yellowing of leaves in onion. Bolting is also reported to be a problem in onion cultivation which is due to deficiency of boron. In Nagaland condition, some cultivars like Arka Kalayayan, N-53 and Agrifound Dark Red were tested during kharif season and out of which Agrifound Dark Red was found to be most suitable under Medziphema condition.

The use of micronutrients should be made with great caution because of their small amounts needed and interactions with other nutrients. Improvement in onion growth and yield has been reported through micronutrient by many scientists at different types of soils. But very little information is available on these aspects under sub-tropical foothill conditions. Keeping in view, the experiment was undertaken.

Materials and Methods

Location

The experimental farm is located at the foothills of Nagaland at an altitude of 310 m above mean sea level, with the geographical location of 25˚ 45"43' N latitude and 95˚ 53"04' E longitude.

Fertilizer application

Bulbs were planted at a spacing of 15 cm x 15 cm in a plot size of 1.5 m x 1.5 m. FYM @ 25 t ha^{-1} along with N, P and K @ 100:60:60 kg ha^{-1}, respectively and was applied uniformly in all experimental plots in the form of urea, single super phosphate (SSP) and Muriate of Potash (MOP). Urea and MOP was applied in two split doses i.e., at the time of land preparation and second dose 30 days after planting.

Treatment

The experimental field was laid in randomized block design (RBD) with two factors. These were:

Factor A

There were three levels of zinc as follows. The source of zinc was zinc sulphate (Zn_2SO_4)

Zn_0 = 0 kg Zn ha^{-1}
Zn_1 = 25 kg Zn ha^{-1}
Zn_2 = 50 kg Zn ha^{-1}

Factor B

There were three levels of boron as follows. The source of boron was boric acid (H_3BO_3)

B_0 = 0 kg ha^{-1}
B_1 = 2.5 kg ha^{-1}
B_2 = 5 kg ha^{-1}

Treatment combination

T_1- $Zn_0 + B_0$
T_2- $Zn_0 + B_1$
T_3- $Zn_0 + B_2$
T_4- $Zn_1 + B_0$
T_5- $Zn_1 + B_1$
T_6- $Zn_1 + B_2$
T_7- $Zn_2 + B_0$

T_8- $Zn_2 + B_1$
T_9- $Zn_2 + B_2$

Growth parameters

During the initial growth stage randomly five plants were selected to record the observations on plant height and number of leaves per plant. Plant height was measured with the help of meter scale. The number of leaves per plant was counted from five sample plants of each plot at 15 days interval to observe the rate of growth and their average was taken as number of leaves per plant.

The number of bolting in all the plants from each plot were recorded and continued till harvest and their average values were expressed in percentage.

After harvesting, the doubles were counted from the total bulbs of each unit plot and their percentages were calculated using the following formula:

$$\text{Doubling \%} = \frac{No.of\ doubled\ bulbs}{Total\ no.of\ bulbs} \times 100$$

Yield and yield attributing characters

The fresh weight of the bulb from were recorded after the harvest with the help of weighing balance and the average bulb weight for each treatment was worked out and represented in terms of gram.

Neck thickness and bulb diameter was measured with the help of Vernier calliper after harvesting. The yield per hectare in respect of various treatments was calculated by using the following formula:

$$Y = A \times \frac{1000}{S}$$

Where,

A = Yield per plot
S = Plot area
Y = Yield per hectare

The results obtained were expressed in quintal (q/ha).

Quality parameters

Total soluble solids were measured with the help of hand refractometer. Dry weight of leaves and bulbs was determined by keeping them in oven at 50^0C for 73 hours for drying and weighed on electronic balance.

The concentration of zinc in leaves and bulbs was determined by using Atomic Absorption Spectrophotometer (AAS) method (Lindsay and Norwell, 1978), concentration of sulphur in leaves and bulbs was determined by using the Barium Chromate Colorimetric method (Palasker *et al.*, 1981), concentration of boron in leaves and bulbs was determined by Azomethine – H method (John *et al.*, 1975) and the data collected was calculated as part per million on dry weight basis. Similarly, Nitrogen was determined by Kjeldhal method as described by Blake (1965), Phosphorus was estimated by using Vanado Molybdate Yellow colour method (Jackson, 1967) and Potassium content was estimated by Flame- Photometry (Chapman and Pratt, 1961).

Fertility status of the soil after harvest

The soil samples were collected from five spots in each experimental plot after harvesting at a depth of 10-15cm with the help of screw auger. The collected soil samples were mixed and reduced into 500g and dried in shade, grounded and sieved for determination of the following nutrient status.

Organic carbon was determined by Walkey and Blake rapid titration method as described by Piper (1966). The pH of the soil was determined in 1:2 soil water suspension using model LI 120 digital meter (A.O.A.C, 1988). The available soil nitrogen (N) was estimated by alkaline potassium permanganate method as suggested by Subbiah and Asija (1956).The available phosphorus (P_2O_5) was determined by Bray's method (Bray and Kurtz, 1945). The available potassium (K_2O) was determined by Ammonium acetate method (Hanway and Heidal, 1952).

Economics of the treatment

Economics of the different treatments were worked out according to prevailing market prices of inputs and outputs. The cost of cultivation was calculated as per the item wise as well as treatment wise cost incurred in each treatment.

Gross income

Gross income was calculated by multiplication of yield and the selling rate of onion.

Net income

Net income was estimated by deducting the total cost of cultivation (fixed cost+ treatment cost) from gross income of the particular treatment.

Benefit cost ratio

Benefit cost ratio was calculated by the formula:

$$\text{Benefit cost ratio} = \frac{\text{total output}}{\text{total input}}$$

Method of analysis

The data recorded during the course of investigation were statistically analyzed by the analysis of variance method (Panse and Sukhatme, 1978) and the significance of different sources of variation were tested by error mean square using Fisher Schedecor 'F' test of probability of 5% level of significance.

Results and Discussion

An examination of the data presented in table 1, strongly showed that there was a significant effect of soil application of zinc and boron on vegetative growth parameters of onion plants. Soil application of onion plants with treatment combination of Zn 25 kg ha^{-1} and B 5 kg ha^{-1} resulted in the highest value of vegetative growth parameters. The maximum plant height (57.47 cm) was recorded in treatment combination (Zn 25 kg ha^{-1} + B 5 kg ha^{-1}) and the minimum (39.57 cm) under control. The maximum number of leaves (12.37 plant^{-1}) was obtained from treatment combination (Zn 25 kg ha^{-1} + B 5kg ha^{-1}) and the minimum from control (7.97 plant^{-1}). The highest neck thickness of bulbs (1.68 cm) at maturity stage was found in treatment combination (Zn 25 kg ha^{-1} + B 5 kg ha^{-1}) and lowest (1.15 cm) under control. Bolting percentage was found to be highest (4.93 %) in treatment combination Zn_2B_2 (Zn 50 kg + B 5 kg ha^{-1}) and lowest (4.27 %) in treatment (Zn 25 kg + B 5 kg ha^{-1}). Doubling percentage was found to be highest (5.60 %) in treatment combination (Zn 50 kg ha^{-1} + B 5 kg ha^{-1}) and lowest (4 %) in treatment (Zn 25 kg ha^{-1} + B 2.5 kg ha^{-1}).

Therefore, it was found that combination of zinc and boron plays an active role in vegetative growth of onion plant. These results are in accordance with the investigation of Alam *et al.,* (2010), Jawaharlal *et al.,* (1996), Ballabh *et al.,* (2013) and Ali (2013). The favourable effect of micronutrients on plant growth might be due to its role in many physiological processes and cellular functions within the plants. In addition, they play an essential role in improving plant growth, through biosynthesis of endogenous hormones which is responsible for promoting of plant growth (Hansch and Mendel, 2009). These results were also reported by Ballabh *et al.*, (2013).

Increase in growth attributes might be due to the fact that besides the role of zinc in chlorophyll formation, it also influenced cell division, meristematic activity of tissues, and expansion of cell and formation of cell wall (Chhipa, 2005). The positive effects due to application of boron also may be probably due to the beneficial effects as it helps in cell division and also increases calcium content of growing tissues thereby causing better vegetative growth. The beneficial effect of boron on growth parameters was reported by Manna *et al.*, (2011), Chanchan *et al.*, (2013) and Acharya *et al.*, (2014). Therefore the combined effect of zinc and boron was found to be most superior in comparison with single effect and control. These findings also are in conformity with the findings of Manna *et al.*, (2011), Singh *et al.*, (2005), Quddus *et al.*, (2009) and Alam *et al.*, (2010), Ali (2013) and Acharya *et al.*, (2014).

A perusal of data presented in table 2 revealed that all the treatments were found significantly superior to control. The maximum bulb diameter (6.83 cm) was obtained by applying Zn 25 kg + B 5 kg ha^{-1} followed by Zn 50 kg + B 5 kg ha^{-1} (6.30 cm). The highest of bulb weight (110.80 g) was recorded from the treatment combination (Zn 25 kg + B 5 kg ha^{-1}) and the lowest bulb weight was found in control. The highest shoot: bulb ratio (0.48) was recorded from treatment combination (Zn 25 kg + B 5 kg ha^{-1}) and the lowest was found in control (0.27). Yield data presented in table 3 shows that zinc and boron produced significant variations for bulb yield of onion. The maximum bulb yield per plot (5.32 kg) was recorded from (Zn 25 kg + B 5 kg ha^{-1}) while the lowest was found in control (2.31 kg). Similarly the highest bulb yield per hectare (236.59 q) was recorded in treatment (Zn 25 kg + B 5 kg ha^{-1}) and the lowest (102.66 q) was found in control. The treatment combination (Zn 25 kg + B 5 kg ha^{-1}) performed as the highest yielder by 59 percent, over control.

A significant variation was found in respect of yield and yield attributing characters due to the effect of different treatments combination of zinc and boron. The yield advantages of different treatment combinations were due to better growth and development. Thus higher photosynthates accumulation in the bulbs for higher leaves per plant would ensure higher individual bulb weight, large bulb diameter and neck thickness. This might be due to the main function of zinc in plant as a metal activator of several enzymes like dehydrogenase, proteinase and peptidases (Prasad and Kumar, 2010). The beneficial effect of zinc on the yield parameters may be attributed due to the fact that soil application of zinc resulted in increased supply of the available zinc to the plants which led to proper growth and development because essential role of zinc has been established as a component of several enzymes which are concerned with carbohydrate and nitrogen metabolism, in addition to its involvement directly or indirectly in regulating the various physiological processes of plants (Marschner, 1995). The findings were in conformity with the findings of Jawaharlal *et al.*, (1986), Khan *et al.*, (2007), Thakare *et al.*, (2007) and Ballabh *et al.*, (2013).

The increase in the yield by boron application may be due to its role in enhancing the translocation of carbohydrates from the site of its synthesis to the storage tissue as boron is known to play beneficial role in the translocation of carbohydrates (Sisler *et al.*, 1956). These results are in agreement based on experimental evidence by Mishra *et al.*, (1990), Chermsiri *et al.*, (1995) and Devi *et* *al.*, (2009). More-over, applied boron and zinc in combination of nitrogen, phosphorus, potash and FYM undoubtedly increased the yield, indicating that the soil was deficient in those nutrients. Thus the interaction effect between zinc and boron was found to be most effective as compared to single dose of zinc and boron and control. These results are in congruity with works done by Halder *et al.*, (2007), Quddus *et al.*, (2009), Ali (2013) and Acharya *et al.*, (2014).

The data presented in table 3 showed that there was a significant effect of soil application of zinc and boron on quality parameters of onion plant. The effects of zinc and boron on quality of onion was studied in terms of dry matter of leaves and bulbs, TSS, zinc, boron, sulphur, nitrogen, potassium, phosphorus and content in leaves and bulbs. Application of zinc and boron significantly influenced the dry weight of onion. The maximum dry weight of leaves (17.33 g) was recorded in Zn 50 kg + B 2.5 kg ha^{-1} while the lowest was found in control (8.60g). Dry weights of bulb (14.30 g) were observed higher in Zn 25 kg + B 5 kg ha^{-1} which gave 31.4 per cent increase in dry weight of bulbs over control (9.80 g). The treatment Zn 25 kg + B 5 kg ha^{-1} recorded the maximum TSS of 13.98 ^{O}B followed by Zn 50 kg ha^{-1} (13.11 ^{O}B) and the lowest was recorded from control (9.77 ^{O}B). The findings are also in collaboration with works done by Singh and Ram (2001), Srivastava *et al.*, (2005) and Trivedi (2013) and Ballabh (2013). Ali (2013) reported that the dry matter content was recorded maximum from nutrient combination of Zn 3 kg+ B 2 kg+ Mo 1 kg+ S 15 kg+ N 100 kg+ P 35 kg+ and K 100 kg ha^{-1}. Further, Alam *et al.*, (2010) and Sindhu and Tiwari (1993) also reported that combination effect between zinc and boron enhanced the qualitative characters.

From the investigation it was also evident that soil application of various doses of boron not only altered the quantitative characters but also enhanced the qualitative characters like dry weight of leaves. These results are in conformity with works done by Manna *et al.*, (2011), Hania (2012) and Devi *et al.*, (2009). The improvement in total soluble solids (TSS) content in treated bulbs due to micronutrients might be attributed to enhance metabolic processes involved in biosynthesis of total soluble solids such as carbohydrates, organic acid, amino acids and other inorganic constituents. The enhancement in all such bio-chemical constituents might have caused an increase in TSS (Total soluble solids) and dry matter. This work is in relation with experiment conducted by Ballabh (2013) where he reported that Zn @ 4 mg L^{-1} gave the maximum TSS. The findings were also in relation with works done by Singh and Ram (2001), Srivastava *et al.*, (2005) and Trivedi (2005).

Also from table 3 it is evident that the treatment Zn 25 kg + B 5 kg ha^{-1} recorded the highest zinc content in leaves (41.27 ppm) and bulbs (55.33 ppm) and also in boron content in leaves (13.87) and bulbs (14.43) while the lowest was found in control. The sulphur content in leaves (2196.7 ppm) and in bulb (2244 ppm) was found to be highest in treatment Zn 50 kg + B 5 kg ha^{-1} and the lowest was found in control. The application of zinc in soil might have increased the availability of zinc in the rhizosphere. The favourable effect of zinc on photosynthesis and metabolic processes might have augmented the production of photosynthesis and their translocation to different plant parts, which ultimately increased the concentration of nutrients in the plant. It has been observed that boron nutrition has also positively increased the concentration of both macro and micro nutrients in onion. Similar results were also reported by Mishra *et al.*, (1990), Balyan *et al.*, (1994), Yadav *et al.*, (2006), Chhippa (2005) and Lal (2012).

Table.1 Effect of zinc and boron on growth parameters of onion

Treatment	Plant height (cm)	Leaves $plant^{-1}$	Neck thickness (cm)	Bolting (%)	Doubling (%)
Zinc					
Z_0 (Control)	42.11	9.84	1.39	4.46	4.82
Z_1 (25 kg ha^{-1})	52.19	11.87	1.56	4.42	4.72
Z_2 (50 kg ha^{-1})	49.22	12.34	1.61	4.47	4.88
CD at 5%	3.49	1.21	0.10	0.18	NS
Boron					
B_0 (Control)	45.42	11.46	1.44	4.30	5.12
B_1 (2.5 kg ha^{-1})	48.30	10.82	1.49	4.60	4.43
B_2 (5 kg ha^{-1})	49.80	11.78	1.62	4.44	4.86
CD at 5%	3.49	NS	0.10	0.18	0.49
Zinc x Boron					
Z_0B_0 (Control)	39.57	7.97	1.15	4.20	5.13
Z_1B_1 (25 kg + 2.5 kg ha^{-1})	50.57	10.50	1.43	4.43	4.00
Z_1B_2 (25 kg + 5 kg ha^{-1})	57.47	12.37	1.68	4.27	4.70
Z_2B_1 (50 kg + 2.5 kg ha^{-1})	47.63	11.73	1.62	4.33	4.27
Z_2B_2 (50 kg + 5 kg ha^{-1})	51.87	11.63	1.60	4.93	5.60
CD at 5%	6.05	2.09	0.18	NS	0.85

Table.2 Effect of zinc and boron on yield parameters of onion

Treatment	Bulb Diameter (cm)	Bulb weight (g)	Shoot: bulb	Yield $plot^{-1}$ (kg)	Yield ha^{-1} (q)
Zinc					
Z_0 (Control)	5.26	76.8	0.33	3.11	138.42
Z_1 (25 kg ha^{-1})	6.09	96.96	0.42	4.79	212.94
Z_2 (50 kg ha^{-1})	6.08	89.93	0.39	4.56	202.52
CD at 5%	0.25	2.95	NS	0.19	8.30
Boron					
B_0 (Control)	5.23	77.03	0.34	3.58	159.26
B_1 (2.5 kg ha^{-1})	5.94	90.33	0.38	4.22	187.51
B_2 (5 kg ha^{-1})	6.24	96.32	0.40	4.66	207.11
CD at 5%	0.24	2.95	NS	0.19	8.30
Zinc x Boron					
Z_0B_0 (Control)	4.40	64.20	0.27	2.31	102.66
Z_1B_1 (25 kg + 2.5 kg ha^{-1})	5.93	95.20	0.40	4.76	211.41
Z_1B_2 (25 kg + 5 kg ha^{-1})	6.83	110.80	0.48	5.32	236.59
Z_2B_1 (50 kg + 2.5 kg ha^{-1})	6.13	89.37	0.39	4.57	202.96
Z_2B_2 (50 kg + 5 kg ha^{-1})	6.30	98.40	0.37	4.96	220.30
CD at 5%	0.42	5.12	NS	0.32	14.38

Table.3 Effect of zinc and boron on quality parameters of onion

Treatment	Dry weight/100 g fresh weight		TSS (^{0}B)	Zinc content (ppm)		Boron content (ppm)		Sulphur content (ppm)	
	Leaf	Bulb		Leaf	Bulb	Leaf	Bulb	Leaf	Bulb
Zinc									
Z_0 (Control)	10.69	11.13	11.05	21.90	36.34	8.40	10.50	1871.9	1886.3
Z_1 (25 kg ha^{-1})	14.26	12.93	13.10	33.20	47.51	10.50	12.69	2138.1	2068.9
Z_2 (50 kg ha^{-1})	15.53	12.90	13.11	33.82	47.86	9.311	11.60	2110.3	2165.3
CD at 5%	3.22	0.51	0.75	1.19	1.46	0.61	0.47	73.73	85.47
Boron									
B_0 (Control)	12.28	11.14	11.93	25.33	40.03	6.60	9.29	1949.3	1912.4
B_1 (2.5 kg ha^{-1})	14.30	12.70	12.24	29.29	44.13	9.567	11.86	2051.4	2019.1
B_2 (5 kg ha^{-1})	13.90	13.12	13.08	34.30	47.54	12.04	13.64	2119.6	2189.0
CD at 5%	3.22	0.509	0.75	1.19	1.46	0.61	0.47	73.73	85.47
Zinc x Boron									
Z_0B_0 (Control)	8.60	9.80	9.77	17.97	32.73	4.80	7.17	1739.3	1801.3
Z_1B_1 (25 kg + 2.5 kg ha^{-1})	13.63	13.0	12.70	31.23	44.63	10.13	13.07	2113.0	2019.0
Z_1B_2 (25 kg + 5 kg ha^{-1})	14.70	14.30	13.98	41.27	55.33	13.87	14.43	2120.3	2244.7
Z_2B_1 (50 kg + 2.5 kg ha^{-1})	17.33	13.50	13.07	32.10	50.67	10.43	11.67	2116.7	2159.0
Z_2B_2 (50 kg + 5 kg ha^{-1})	15.47	13.07	12.87	38.43	48.10	10.00	11.67	2196.7	2344.0
CD at 5%	5.58	0.88	1.29	2.07	2.54	1.06	0.82	NS	NS

Table.4 Effect of zinc and boron on NPK content in onion

Treatment	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)	
Zinc	**Leaf**	**Bulb**	**Leaf**	**Bulb**	**Leaf**	**Bulb**
Zn_0 - Control	0.93	1.22	0.32	0.20	1.26	1.29
Zn_1- Zn @ 25 kg ha^{-1}	1.37	1.43	0.42	0.35	1.61	1.77
Zn_2- Zn @ 50 kg ha^{-1}	1.32	1.38	0.32	0.36	1.56	1.62
CD at 5%	0.14	NS	NS	0.12	0.17	0.21
Boron						
B_0- Control	1.07	1.23	0.29	0.27	1.37	1.32
B_1- B @ 2.5 kg ha^{-1}	1.22	1.34	0.45	0.26	1.41	1.61
B_2- B @ 5 kg ha^{-1}	1.33	1.46	0.31	0.38	1.65	1.74
CD at 5%	0.14	NS	NS	NS	0.17	0.21
Zinc x Boron						
Zn_0 + B_0- Control	0.71	1.14	0.11	0.12	0.93	0.76
Zn_1 + B_1- Zn @ 25 kg ha^{-1} + B @ 2.5 kg ha^{-1}	1.37	1.48	0.29	0.22	1.33	1.74
Zn_1 + B_2- Zn @ 25 kg ha^{-1} + B @ 5 kg ha^{-1}	1.49	1.60	0.58	0.47	1.77	1.85
Zn_2 + B_1- Zn @ 50 kg ha^{-1} + B @ 2.5 kg ha^{-1}	1.33	1.27	0.52	0.34	1.62	1.63
Zn_2 + B_2- Zn @ 50 kg ha^{-1} + B @ 5 kg ha^{-1}	1.40	1.52	0.02	0.41	1.59	1.73
CD at 5%	NS	NS	NS	NS	0.29	0.37

Table.5 Effect of zinc and boron on fertility status of the soil after harvest

Treatment	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Organic carbon (%)	pH
Zinc					
Zn_0 - Control	337.37	13.36	157.38	1.44	5.14
Zn_1- Zn @ 25 kg ha^{-1}	342.22	15.12	199.23	1.59	5.04
Zn_2- Zn @ 50 kg ha^{-1}	354.06	15.68	218.56	1.75	4.93
CD at 5%	9.37	0.98	12.88	0.06	0.10
Boron					
B_0- Control	312.45	14.17	169.02	1.55	4.99
B_1- B @ 2.5 kg ha^{-1}	371.18	15.18	207.71	1.62	5.11
B_2- B @ 5 kg ha^{-1}	350.03	14.81	198.43	1.61	5.02
CD at 5%	9.37	NS	12.88	0.06	NS
Zinc x Boron					
Zn_0 + B_0- Control	283.41	11.22	132.86	1.33	5.06
Zn_1 + B_1- Zn @ 25 kg ha^{-1} + B @ 2.5 kg ha^{-1}	360.08	16.10	231.53	1.61	5.13
Zn_1 + B_2- Zn @ 25 kg ha^{-1} + B @ 5 kg ha^{-1}	328.11	14.26	212.04	1.42	4.93
Zn_2 + B_1- Zn @ 50 kg ha^{-1} + B @ 2.5 kg ha^{-1}	377.96	15.83	212.52	1.67	4.96
Zn_2 + B_2- Zn @ 50 kg ha^{-1} + B @ 5 kg ha^{-1}	368.74	14.91	223.07	2.04	5.00
CD at 5%	16.22	1.70	22.30	0.11	NS

Table.6 Economics of the treatment

Treatment	Cost of cultivation (Rs. ha^{-1})			Yield (q ha^{-1})	Gross income @ Rs.1100 q^{-1}	Net income (Rs. Ha^{-1})	Benefit: cost ratio
	Fixed cost	Treatment cost	Total				
T_1 - Control	46,460	-	46,460	102.66	112,926	66,466	1:1.43
T_2 - NPK @ 100:60:60 kg ha^{-1} + FYM @ 2.5 t^{-1} + B @ 2.5 kg ha^{-1}	46,460	500	46,960	148.15	162,965	116,005	1:2.47
T_3 - NPK @ 100:60:60 kg ha^{-1} + FYM @ 2.5 t^{-1} + B @ 5 kg ha^{-1}	46,460	1000	47,460	164.45	180,895	133,435	1:2.81
T_4 - NPK @ 100:60:60 kg ha^{-1} + FYM @ 2.5 t^{-1} + Zn 25 kg ha^{-1}	46,460	1450	47,910	190.81	209,891	161,981	1:3.38
T_5 - NPK @ 100:60:60 kg ha^{-1} + FYM @ 2.5 t^{-1} + Zn 25 kg ha^{-1} + B 2.5 kg ha^{-1}	46,460	1950	48,410	211.41	232,551	184,141	1:3.80
T_6 - NPK @ 100:60:60 kg ha^{-1} + FYM @ 2.5 t^{-1} + Zn 25 kg ha^{-1} + B 5 kg ha^{-1}	46,460	2450	48,910	236.59	260,249	211,339	1:4.3
T_7 - NPK @ 100:60:60 kg ha^{-1} + FYM @ 2.5 t^{-1} + Zn 50 kg ha^{-1}	46,460	2900	49,360	184.30	202,730	153,370	1:3.1
T_8 - NPK @ 100:60:60 kg ha^{-1} + FYM @ 2.5 t^{-1} + Zn 50 kg ha^{-1} + B 2.5 kg ha^{-1}	46,460	3400	49,860	202.96	223,256	173,396	1:3.48
T_9 - NPK @ 100:60:60 kg ha^{-1} + FYM @ 2.5 t^{-1} + Zn 50 kg ha^{-1} + B 5 kg ha^{-1}	46,460	3900	50,360	220.30	242,330	191,970	1:3.81

Zinc being an essential component of many enzymes and because of playing a major role in the absorption of moisture, its doses up to certain levels might have increased the content of zinc in the bulbs. Similarly, an increased level of boron increased the boron content, but decreased the zinc contents. Yadav *et al.,* (2006) showed a contradictory effect of zinc and boron in tomato. These results are also in collaboration with Kumar *et al.,* (2007), Chhipa (2005) and Lal (2012). The combination effect between zinc and boron proved to give best results when comparison with single doses of zinc and boron and control in relation with zinc and boron content in leaves but it did not have any significant influence on sulphur accumulation in leaves. Mishra (1990), Rafique and Mahmood-ul-Hassan (2008), Chhipa *et al.,* (2005), Ballabh *et al.,* (2013) and Ali (2013) observed increased contain of total soluble solids (TSS), dry matter content, zinc, boron and sulphur content in onion by application of micronutrients.

It is apparent from the data presented in table 4 that in leaves, highest N (1.49%), P (0.58%) and K (1.77%) was found in Zn_1+B_2 (Zn 25 kg ha^{-1} + B 5 kg ha^{-1}) while the lowest nitrogen (0.71%), phosphorus (0.11%) and potassium (0.93%) was found under control. The maximum content of nitrogen (1.60%), phosphorus (0.47%) and potassium (1.85%) in bulb was found in Zn_1+B_2 (Zn 25 kg ha^{-1}+ B 5 kg ha^{-1}) while the lowest nitrogen (1.14%), phosphorus (0.12%) and potassium (0.76%) was found under control. Roy (1992) studied the effect of B, Zn and Fe in different combinations and observed that micro-nutrients enhanced the N, P and K content in rhizome and further reported that application of Zn, B and Fe to ginger resulted increase in the concentration of N, P and K in leaves. The beneficial role of zinc in increasing CEC of roots might have helped in increasing absorption of nutrient from the soil. Further, the beneficial role of Zn in chlorophyll formation, regulating auxin concentration and its stimulatory effect on most of the physiological and metabolic process of plant, also might have helped plants in absorption of greater amount of nutrients from the soil. Boron is found involved in the availability of nitrogen to the plants and synthesis of cell wall components, hence, increasing level of boron increased the nitrogen content in the bulbs. Mishra *et al.,* (1990) reported that application of borax @ 10 kg ha^{-1} intensified the magnitude of B uptake in onion bulbs. Similar findings are in concurrent with the works done by Dixit (1997), Suman *et al.,* (2002) and Devi *et al.,* (2009).

The presented in table 5 apparently showed that zinc and boron nutrition gave positive impact on improving the fertility level of the soil. The highest (2.04 %) organic carbon content in the soil was found in treatment combination Zn_2B_2 (Zn 50 kg ha^{-1} + B 5 kg ha^{-1}) followed by Zn_2B_1 (Zn 50 kg ha^{-1} +B 2.5 kg ha^{-1}) with organic carbon percentage of 1.67% while the lowest (1.33%) was found under control.

The pH of the soil decreased with application of zinc and boron as the highest pH of 5.14 was found under control while the lowest pH of 4.93 was found in Zn_2 (Zn 50 kg ha^{-1}) and in treatment combination Zn_1+B_2 (Zn 25 kg ha^{-1}+B 5 kg ha^{-1}).

The maximum available nitrogen (377.96 kg ha^{-1}) was found in treatment combination Zn_2+ B_1 (Zn 50 kg ha^{-1} + B 2.5 kg ha^{-1}) while the maximum available phosphorus (16.10 kg ha^{-1}) and potassium (231.53 kg ha^{-1}) was found in Zn_1+B_1 (Zn 25 kg ha^{-1}+ B 2.5 kg ha^{-1}) which were significantly superior to many treatments. The lowest available nitrogen (283.41 kg ha^{-1}), phosphorus (11.22 kg ha^{-1}) and potassium (132.86 kg ha^{-1}) was found under control.

The economics of the fertilizer treatments presented in table 6 revealed that the integrated nutrient management had an appreciable impact on the total yield as well as gross income and net return. The highest net income (Rs.211,339 ha^{-1}) with a benefit cost ratio of 1:4.3 was obtained from treatment combination Zn_1+B_2 (Zn 25 kg ha^{-1} + B 5 kg ha^{-1}) followed by treatment combination Zn_2+ B_2 (Zn 50 kg ha^{-1}+ B 5 kg ha^{-1}) with a net income of Rs.191,970 and benefit cost ratio of 1:3.81. The lowest net income of Rs.66,466 with a benefit cost ratio of 1:1.43 was found under control. Most of the treatment combinations were found to increase the net income and benefit cost ratio in comparison to control. The results were in close conformity with the previous work conducted by Kumar and Sen (2005), Chhipa *et al.,* (2005) and Nasreen *et al.,* (2009).

Based on the experimental finding, it can be concluded that soil application of Zn 25 kg ha^{-1} + B 5 kg ha^{-1} could improve plant growth parameters, yield and quality characters of onion bulbs under sub-tropical foothill condition. The application of zinc and boron also showed a profound residual effect on sustaining the fertility status of the soil after the harvest. Thus based on the support warranted from the above data, it can be concluded that growing of onions by judicious use of combined application of micro and macro nutrients is the best practice in sustaining productivity and soil health and hence can be practiced by the growers effectively under the foot hills of Nagaland condition.

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