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Could maneuvering the methods of zinc and boron application influences yield and agro-morphological traits of brinjal in inceptisols?

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Abstract
Brinjal is one of the widely grown vegetable with high nutritive value responsive to applied Zn and B in deficient soils. With this background, a pot experiment was conducted at College of Horticulture Farm to study the effect of FYM, zinc and boron on yield and agro-morphological characters of brinjal where two levels of FYM (0 and 5 t ha^{-1}), four levels of Zn (Zn_0: No Zn, Zn_1: 5.0 kg Zn ha^{-1} as basal, Zn_2: 10.0 kg Zn ha^{-1} as basal and Zn_3: 5.0 kg Zn ha^{-1} as basal + Foliar spray of Zn twice @ 0.5% $ZnSO_4.7H_2O$ solution) and three levels of B (B_0: No B, B_1: 1kg B ha^{-1} and B_2: 2 kg B ha^{-1}) were applied in factorial completely randomized design. The application of Zn and B significantly influenced the fruit yield and other agro-morphological parameters *viz*., number of fruits per plant, plant height, fruit diameter and fruit length of brinjal. The highest increase was found with the conjoint application of soil + foliar application of Zn and highest dose of B *i.e.* 2.0 kg B ha^{-1} along with FYM. On average, fruit yield of brinjal varied between 0.92 to 1.31 kg pot^{-1} with a mean value of 1.12 kg pot^{-1}. Zinc application @ 10.0 kg ha^{-1} through basal (Zn_2) as well as soil + foliar application of Zn (Zn_3) significantly enhanced the fruit yield of brinjal over the application of 5.0 kg Zn ha^{-1} as well as over the control. Application of Zn fertilizers along with FYM enhanced the brinjal fruit yield to the extent of 10-24% over the control under different treatment combinations of Zn (either soil application or through soil plus foliar application), whereas, application of B increased the fruit yield to the tune of 12 to 17% compared to no B application. The interaction between FYM and Zn and well as between FYM and B had also shown significant positive effect towards fruit yield of brinjal.

Keywords: Brinjal nutrition, boron, farm yard manure, fruit yield and zinc

Introduction
Agricultural intensification resulted in a serious depletion in micronutrients reserve in soils and degradation of environment, along with many other pitfalls. Following such intensification, widespread deficiencies of micronutrients particularly zinc (Zn), boron (B) and iron (Fe) in soils are reported across the globe. And it causes a serious depletion in their loading in edible parts of crops affecting not only crop yield but also its quality. Brinjal (*Solanum melongena* L.) is highly productive and usually finds its place as poor man's crop. It is an important vegetable due to its nutritive value, consisting of minerals like iron, phosphorus, calcium and vitamins particularly 'B' group (Mahmoud, 2000) [8]. Analysis of soil and plant samples has indicated that 49% soils in India are potentially deficient in Zn, 12% Fe, 5% Mn, 3% Cu, 33% B and 11% in Mo (Singh, 2008) [16]. Basal application to soil and/or foliar sprays of Zn, B and Mo and foliar sprays of Fe and Mn have been recommended as the most suitable methods for correcting such deficiencies in crops (Shukla *et al*., 2016) [15]. Micronutrients like iron, zinc and boron are necessary for plant development and metabolism and also play a positive role in increasing fruit yield and as well as fruit quality in brinjal. Various responses were observed in growth and yield in crop species and in cultivars to trace elements deficiency (Fageria, 2009) [1]. Plants take zinc in the ionic form (Zn^{++}) or in a complex type with a chelating substance e.g., EDTA. Salts or complexes of zinc can be simply absorbed straight through leaves.

Foliar spray of micronutrients facilitates efficient consumption of nutrients straightly through leaves, the effect of which can show its importance soon (Sharma and Brar, 2008) [14]. Response of brinjal as well as other high value vegetable crops to soil as well as foliar application of Zn and B has been reported by several workers in India. However, reports and literatures on application of those nutritionally important micronutrients along with the application of farm yard manure (FYM) in vegetables and in particular brinjal is scanty. Under these circumstances, it is hypothesized that yield and yield attributing traits (*viz*. plant height, number of fruits per plant, fruit dimensions like fruit girth and fruit length) of brinjal is influenced by its micronutrient nutrition through different modes of application along with the FYM. As such we studied the effects of different doses and methods of application of Zn, different doses of B in conjugation with FYM on growth (yield related agro-morphological parameters) and fruit yield of brinjal.

Materials and Methods

Administration of treatments

A pot experiment was conducted at Nalanda College of Horticulture, Bihar Agricultural university, Noorsarai, Nalanda, India located at $25^0$25'N latitude and $85^0$15'E longitude to study the effect of FYM, zinc and boron on yield and yield related agro-morphological attributes of brinjal as a test crop (var. Navkiran) for the consecutive two years (2012-13 and 2013-14) where two levels of FYM (0 and 5 t ha^{-1}), four levels of Zn (Zn_0: No Zn, Zn_1: 5.0kg Zn ha^{-1} as basal, Zn_2: 10.0kg Zn ha^{-1} as basal and Zn_3: 5.0kg Zn ha^{-1} as basal + Foliar spray of Zn twice @ 0.5% $ZnSO_4.7H_2O$ solution) and three levels of B (B_0: No B, B_1: 1kg B ha^{-1} and B_2: 2kg B ha^{-1}) were applied in factorial RBD. Half of N along with the full amount of P and K were applied during the time of final land preparation and the rest half of N was given into two equal splits-50% at 30 DAT and another 50% at 45 DAT. Zinc was applied at 0.5% concentration (in the form of zinc sulphate heptahydrate) as foliar spray twice at 45 and 60 days after transplanting of brinjal seedlings.

Yield and yield related characters

The total fruit yield per pot of brinjal were recorded after harvesting. Various yield attributing parameters like plant height, fruit length and fruit diameter, number of fruits per plant were also recorded during crop growth and/or after harvesting. Each observations were taken in triplicate to minimize the replication error.

Initial soil properties

Initial soil samples were collected at 0-20 cm depth. They were analyzed for pH, bulk density, organic carbon (Jackson, 1973) [5], available N (Subbaiah and Asija, 1956) [17], P (Olsen *et al*., 1954) [10], K (Hanway and Heidel, 1952) [3], Fe, Mn, Cu and Zn (Lindsay and Norvell, 1978) [7], B (Wolf, 1971) [18].

Results and Discussion

Initial physico-chemical properties of the soil

Initially, the experimental soil was neutral in reaction; soil pH was 6.72. Bulk density of the soils ranged from 1.21 to 1.31 Mg m^{-3} with a mean of 1.24 Mg m^{-3}. Soils were medium in organic carbon content; the value of which is 0.69%. On an average, available N, P and K status of the initial soil was 310.3, 16.9 and 156.2 kg ha^{-1}, respectively which indicated that the soil was medium with respect to available N, P and K content. Soils were low in available B content and the value of available B was 0.57mg kg^{-1}, whereas, DTPA extractable available Fe, Mn, Cu and Zn content of the initial soil was 45.3, 7.9, 2.4 and 0.61mg kg^{-1} respectively.

Fruit yield and yield attributing characters of brinjal

Fruit yield

Results showed that on an average, fruit yield of brinjal varied between 0.92 to 1.31 kg pot^{-1} with a mean value of 1.12 kg pot^{-1} (Table 1). Zinc application @ 10.0 kg ha^{-1} through basal (Zn_2) as well as soil + foliar application of Zn (Zn_3) significantly enhanced the fruit yield of brinjal over the application of 5.0 kg Zn ha^{-1} as well as over the control. Application of Zn fertilizers along with FYM enhanced the brinjal fruit yield to the extent of 10-24% over the control under different treatment combinations (Fig. 1a). FYM and Zn application together showed a significant positive interaction towards the yield increment of brinjal. Results also revealed that Boron application @ 1.0 kg ha^{-1} as well as 2.0 kg ha^{-1} significantly enhanced the brinjal fruit yield to the tune of 12.0 and 17.0% respectively, over the control (Fig. 1b). These results were in conformity with those of Pandav *et al*. (2016) [11] in brinjal as well as in other vegetable crops. Ravichandran *et al.*, (1995) [13] reported the highest brinjal fruit yield with soil application of 25 kg ha-1 $ZnSO_4$ along with 2.5 per cent foliar spray of $ZnSO_4$ at 30 days after transplanting on zinc deficient salty clay loam soil of Annamalai Nagar in Tamil Nandu. Similarly on alluvial soils in different parts of the country, soil application of $ZnSO_4$ corrected Zn deficiency symptoms and significantly increased fruit yield (Raj *et al*., 2001; Sharma and Brar, 2008) [12, 14].

Table 1: Fruit yield (kg pot^{-1}) of brinjal upon application of FYM, Zn and B.

Treatments		Zn_0	Zn_1	Zn_2	Zn_3	Mean
FYM_0	B_0	0.92	0.95	1.09	1.08	1.01
	B_1	0.96	1.09	1.21	1.30	1.14
	B_2	1.01	1.11	1.24	1.27	1.16
	Mean	0.96	1.05	1.18	1.22	1.10
FYM_1	B_0	0.96	0.97	1.08	1.09	1.03
	B_1	0.97	1.13	1.24	1.26	1.15
	B_2	1.06	1.22	1.35	1.31	1.23
	Mean	1.00	1.11	1.22	1.22	1.14
Overall	B_0	0.94	0.96	1.09	1.08	1.02
	B_1	0.97	1.11	1.22	1.28	1.15
	B_2	1.03	1.16	1.30	1.29	1.19
	Mean	0.98	1.08	1.20	1.22	1.12
	FYM	Zn	B	FYM × Zn	FYM × B	Zn × B	FYM × Zn × B
SE(±m)	0.009	0.013	0.012	0.019	0.016	0.023	0.033
CD(0.05)	0.026	0.037	0.032	0.053	0.046	0.065	0.092

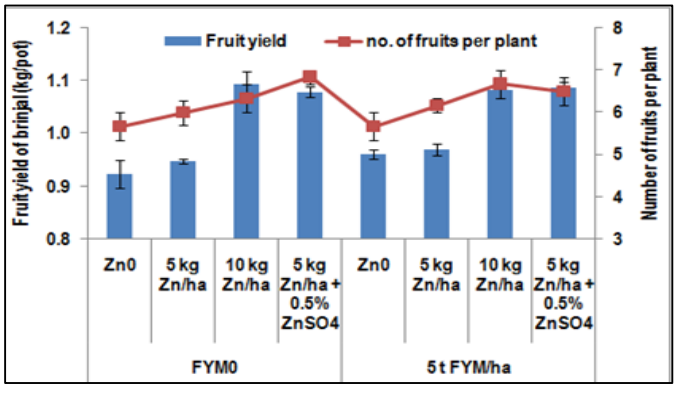

Fig 1a: Fruit yield and no. of fruits per plant upon application of FYM and Zn

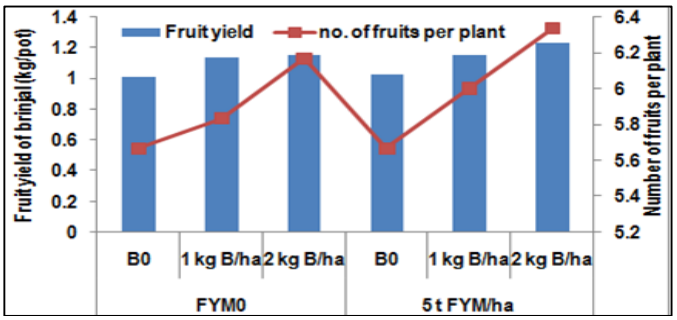

Fig 1b: Fruit yield and no. of fruits per plant upon application of FYM and B

Number of fruits per plant

On an average, number of fruits per plant of brinjal varied from 5.67 to 7.0 across the treatments with a mean value of 6.47 (Table 2). Application of Zn through soil (Zn_2) as well as soil plus foliar (Zn_3) along with FYM increased the number of fruits per plant to the extent of 12.5 and 15.4% respectively over the control (Fig. 1a). The maximum number of fruits per plant was recorded under soil plus foliar application of Zn (Zn_3) in combination with highest dose of B application (B_2) along with FYM, whereas lowest number of fruits per plant was recorded under control. Thus, it can be opined that soil plus foliar application of Zn had an edge over the sole application of higher dose of Zn fertilizers in enhancing number of fruits per plant of brinjal and in turn yield of the crop. Results also revealed that application of B had only little effect at higher doses (B_2) as compared to lower dose (B_1) of B, although both the treatments significantly increased the number of fruits per plant as compared to without B application (Fig. 1b). Results are in line with the findings of Modi *et al*. (2019) [9].

Table 2: Number of fruits per plant of brinjal upon application of FYM, Zn and B.

Treatments		Zn_0	Zn_1	Zn_2	Zn_3	Mean	
FYM_0	B_0	5.67	6.00	6.33	6.83	6.21	
	B_1	5.83	6.33	6.67	7.00	6.46	
	B_2	6.17	6.50	6.83	7.00	6.63	
	Mean	5.89	6.28	6.61	6.94	6.43	
FYM_1	B_0	5.67	6.17	6.67	6.50	6.25	
	B_1	6.00	6.67	6.83	6.83	6.58	
	B_2	6.33	6.67	6.83	7.00	6.71	
	Mean	6.00	6.50	6.78	6.78	6.51	
Overall	B_0	5.67	6.08	6.50	6.67	6.23	
	B_1	5.92	6.50	6.75	6.92	6.52	
	B_2	6.25	6.58	6.83	7.00	6.67	
	Mean	5.94	6.39	6.69	6.86	6.47	
	FYM	Zn	B	FYM x Zn	FYM x B	Zn x B	FYM x Zn x B
SE(±m)	0.08	0.11	0.10	0.16	0.14	0.20	0.28
CD(0.05)	0.23	0.32	0.28	0.45	0.39	0.55	0.78

Plant height

Results showed that plant height of brinjal varied widely upon application of different treatment combinations. On an average, it varied from 83.2 to 88.2 cm with a mean value of 86.0 cm across the treatments. Brinjal plant attained maximum height of 88.2 cm upon conjoint application of 2.0 kg B ha^{-1} and soil plus foliar application of Zn along with FYM while the lowest plant height was recorded without application of Zn and B (Table 3). When the mean effect of each of Zn, B and FYM treatments as well as interaction of FYM with Zn and B were compared along with control, it was observed that application of Zn and B increased the brinjal plant height to the tune of 18.4 and 10.4% respectively over the control. This might be due to zinc is involved in chlorophyll formation which might have favoured cell division, meristematic growth in apical tissue, enlargement of cell and synthesis of new cell wall (singh *et al.*, 1989). These results are in line with the conformity with Ingel *et al*. (2003), who accounted that tallest plant was observed with increased level of zinc.

Table 3: Plant height (cm) of brinjal upon application of FYM, Zn and B.

Treatments		Zn_0	Zn_1	Zn_2	Zn_3	Mean	
FYM_0	B_0	83.17	83.62	83.57	83.08	83.36	
	B_1	84.75	86.36	86.34	86.07	85.88	
	B_2	85.35	87.15	87.39	86.75	86.66	
	Mean	84.42	85.71	85.77	85.30	85.30	
FYM_1	B_0	83.99	85.63	84.59	86.93	85.28	
	B_1	85.21	87.96	87.25	88.08	87.12	
	B_2	86.70	88.37	88.10	88.17	87.83	
	Mean	85.30	87.32	86.65	87.72	86.75	
Overall	B_0	83.58	84.63	84.08	85.00	84.32	
	B_1	84.98	87.16	86.79	87.08	86.50	
	B_2	86.02	87.76	87.74	87.46	87.25	
	Mean	84.86	86.52	86.21	86.51	86.02	
	FYM	Zn	B	FYM x Zn	FYM x B	Zn x B	FYM x Zn x B
SE(±m)	0.16	0.23	0.20	0.32	0.28	0.39	0.56
CD(0.05)	0.45	0.63	0.55	0.90	0.78	1.10	1.55

Fruit dimensions

Results showed that irrespective of treatments, on an average, fruit length and girth of brinjal varied from 7.43 to 7.90 cm and 5.98 to 7.91 cm with mean values of 7.68 and 6.91 cm, respectively (Table 4 and 5). The maximum fruit length (7.90 cm) and fruit girth (7.91 cm) was observed with the combined application of Zn through soil plus foliar spray (Zn_3) and soil application of boron at higher doses (B_2) along with FYM, whereas the minimum fruit length (7.43 cm) and fruit girth (5.98 cm) was recorded with control treatment, respectively. When the mean values of each of Zn, B and FYM treatments were compared along with control, it was observed that both application of Zn and B treatments recorded higher fruit length and girth than that of control treatment. On an average, application of higher doses of B had little effect on length and girth of fruits as compared to lower dose of B; however when it was compared with control, there was a positive effect of B. Thus it indicated that application of 1 kg B ha^{-1} is beneficial for obtaining higher fruit dimensions and in turn, yield of brinjal, while application of 2 kg B ha^{-1} is not economical for the purpose. Results also revealed that soil plus foliar application of Zn (Zn_3) could save a substantial amount of Zn compared to sole application of higher dose of Zn (Zn_2) in obtaining higher fruit dimensions. Results are in line with the findings of Khedr *et al*. (2004) [6] and Gogoi *et al*. (2014) [2].

Table 4: Fruit length (cm) of brinjal upon application of FYM, Zn and B.

Treatments		Zn_0	Zn_1	Zn_2	Zn_3		Mean
FYM_0	B_0	7.43	7.57	7.52	7.44		7.49
	B_1	7.60	7.59	7.71	7.78		7.67
	B_2	7.68	7.74	7.76	7.81		7.75
	Mean	7.57	7.63	7.66	7.68		7.63
FYM_1	B_0	7.44	7.52	7.49	7.55		7.50
	B_1	7.64	7.75	7.89	7.89		7.79
	B_2	7.84	7.81	7.93	7.90		7.87
	Mean	7.64	7.69	7.77	7.78		7.72
Overall	B_0	7.43	7.54	7.51	7.49		7.49
	B_1	7.62	7.67	7.80	7.83		7.73
	B_2	7.76	7.78	7.84	7.86		7.81
	Mean	7.60	7.66	7.72	7.73		7.68
	FYM	Zn	B	FYM x Zn	FYM x B	Zn x B	FYM x Zn x B
SE(±m)	0.041	0.065	0.062	0.102	0.094	0.104	0.179
CD(0.05)	0.146	0.19	0.174	0.272	0.229	0.351	0.46

Table 5: Fruit girth (cm) of brinjal upon application of FYM, Zn and B.

Treatments		Zn_0	Zn_1	Zn_2	Zn_3		Mean
FYM_0	B_0	6.0	6.2	6.6	6.5		6.3
	B_1	6.0	6.8	7.4	7.6		6.9
	B_2	6.2	6.9	7.4	7.6		7.0
	Mean	6.0	6.6	7.1	7.2		6.8
FYM_1	B_0	6.4	6.4	6.7	7.1		6.6
	B_1	6.5	6.8	7.7	7.7		7.2
	B_2	6.5	6.9	7.9	7.9		7.3
	Mean	6.5	6.7	7.4	7.6		7.1
Overall	B_0	6.2	6.3	6.6	6.8		6.5
	B_1	6.3	6.8	7.6	7.7		7.1
	B_2	6.3	6.9	7.6	7.8		7.2
	Mean	6.3	6.7	7.3	7.4		6.9
	FYM	Zn	B	FYM x Zn	FYM x B	Zn x B	FYM x Zn x B
SE(±m)	0.047043	0.066528	0.057615	0.094085	0.08148	0.11523	0.16296
CD(0.05)	0.131726	0.186289	0.161331	0.263452	0.228156	0.322661	0.456312

Conclusions

The application of Zn and B significantly influenced the fruit yield and other agro-morphological parameters *viz*., number of fruits per plant, plant height, fruit dimensions etc. The highest increase was found with the application of soil + foliar application of Zn and highest dose of B *i.e.* 2.0 kg B ha^{-1}. The soil plus foliar application of zinc and basal application of boron in addition to recommended doses of FYM can be an effective practice as compared to the routine practices to deal with low productivity of brinjal due to zinc and boron deficiency of the studied area, and in turn enhance the farmers' income.

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