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Effect of Boron and Zinc Fertilization on Growth and Yield of Cowpea (*Vigna unguiculata* Walp.) in Inceptisols of Arunachal Pradesh

P. Debnath*, S.K. Pattanaaik, D. Sah, G. Chandra[1] and A.K. Pandey
Department of Natural Resource Management, College of Horticulture and Forestry, CAU, Pasighat, 791102, Arunachal Pradesh

A field experiment was conducted with ten treatments to study the effect of boron (B) and zinc (Zn) in cowpea (*Vigna unguiculata* Walp.) in Inceptisols of Arunachal Pradesh. Recommended doses of fertilizers (RDF) applied was N, P_2O_5 and K_2O @ 30, 60 and 50 kg ha^{-1}, respectively. Growth parameters *viz*., plant height, branches per plant and dry matter yield were significantly influenced due to treatments effects. Maximum average plant height (55.8 cm), branches per plant (8.2) and dry matter yield (51.9 g plant^{-1}) were recorded with application of RDF + 1.5 kg B ha^{-1} + 5 kg Zn ha^{-1} (T_9). Nodules dry weight was significantly influenced by Zn treatment apart from B application. The highest amount of nodule formation (5.2 g plant^{-1}) was recorded in T_7 (RDF + 7.5 kg Zn ha^{-1}). Maximum average seed yield (2.24 t ha^{-1}) was also obtained in treatment T_9 and minimum (1.41 t ha^{-1}) in treatment T_1 (RDF). The highest uptake of nitrogen (N) (180.5 kg ha^{-1}), B (0.9 kg ha^{-1}) and Zn (0.93 kg ha^{-1}) was observed under treatment $T_{9,}$ whereas, the lowest uptake was observed under treatments T_1. The maximum uptake of phosphorus (P) (20.4 kg ha^{-1}) and potassium (K) (131.0 kg ha^{-1}) was obtained with treatment T_4 (RDF + 2 kg B ha^{-1}) and least uptake of P (13.0 kg ha^{-1}) and K (79.8 kg ha^{-1}) was recorded under treatments T_7 (RDF + 7.5 kg Zn ha^{-1}). The soil organic carbon content, water holding capacity and available NPK significantly increased in most of the treatments after harvest of cowpea. However, the treatments had no significant influence on change of the soil pH.

Key words: Boron, zinc, cowpea, nutrient uptake, nodulation and soil fertility

Cowpea (*Vigna unguiculata* Walp.) is one of the most important vegetable crops grown as pulse, vegetable and fodder. It is poor man's protein source and considered one of the most ancient human food sources and has probably been used as a crop plant since Neolithic times (Ng and Marechal 1985). Cowpea is an important multipurpose grain legume extensively cultivated in arid and semiarid tropics. It is an important source of nutrients and provides high quality, inexpensive protein to diet based on cereal grains and starchy foods. Cowpea is a good source of food, fodder, vegetables and certain snacks (Singh *et al*. 2012). It is a crop that can be used as catch crop, mulch crop, intercrop, mixed crop and green crop. It has ability to fix atmospheric N_2 in the soil @ 56 kg ha^{-1} in association with symbiotic bacteria under favourable conditions (Mandal *et al*. 2009). The mature cowpea seed contains 24.8% protein, 63.6% carbohydrate, 1.9% fat, 6.3% fiber, 7.4 ppm thiamine, 4.2 ppm riboflavin and 28.1 ppm niacin (Ahlawat and Shivkumar 2005). The protein concentration ranges from about 3 to 4% in green leaves, 4 to 5% in immature pod and 25 to 30% in mature seeds. The amino acid profile reveals that lysine, leusine and phenylanine contents are relatively high in cowpea. Trends in the production of pulse is adversely affected the per capita availability of pulses. In India per capita/day availability of pulses had decreased from 69 g during sixties to 35 g as against the FAO/WHO's current recommendation of 80 g per day (Ali and Gupta 2012).

Cowpea is highly responsive to fertilizer application and dose of fertilizer depends on the initial soil fertility. Although cowpea is a legume, it gives good response to application of recommended dose of fertilizer (Ahlawat and Shivakumar 2005). Boron (B) and zinc (Zn) are the essential plant micronutrients

*Corresponding author (Email: kanupran@yahoo.co.in)
Present address
[1]Division of Forestry Statistics, ICFRE, Dehradun, Uttrahkand

and their importance for crop productivity is similar to that of major nutrients (Rattan *et al*. 2009; Padbhushan and Kumar 2014). Widespread and extensive occurrence of B and Zn deficiency has been reported in the cultivable soils of Arunachal Pradesh (Debnath *et al*. 2015). It is therefore, imperative to apply B and Zn to such soils in addition to major nutrients for obtaining maximum yields. Application of Zn to soil is the most satisfactory way to cure Zn deficiency (Das 2003). Studies on B and Zn fertilizer proved that the application of B and Zn greatly influenced growth, yield and quality of legume crops (Debnath *et al*. 2015). The deficiency symptoms of B and Zn as well as low yield have been recorded on many legume and other field crops including vegetable crops grown in north-eastern Hill region (Kumar *et al*. 2016). The reports on application of micronutrients on yield of legumes for piedmont soil of north eastern Hill region, particularly Arunachal Pradesh are very meager. The study was therefore, conducted to assess the levels of B and Zn fertilization on growth and yield of cowpea grown in soil of East Siang district of Arunachal Pradesh.

Materials and Methods

General characteristics of study area

A field experiment was conducted to assess the responses of cowpea (Var. Kashi Kanchan) to B and Zn application at the research farm (28°07′ N latitude and 95°33′ E longitude) of College of Horticulture and Forestry, Pasighat, Arunachal Pradesh, India during *kharif* season of two consecutive years 2013 and 2014. The soil of experimental site was sandy loam in texture, strongly acidic in reaction (pH 5.5) with organic carbon (OC) content 23.4 g kg^{-1}, cation exchange capacity (CEC) 14.5 cmol(p$^+$)kg^{-1}, available nitrogen (N) 338 kg ha^{-1}, available phosphrus 28.4 kg P_2O_5 ha^{-1}, available potassium (K) 165.7 kg K_2O ha^{-1}, available B 0.27 mg kg^{-1} and DTPA-extracted Zn 0.48 mg kg^{-1}. The experimental area was under humid subtropical climate with average annual rainfall ranging from 4200-5700 mm and mean annual temperature of 23 ^{o}C.

Field experiment

The field experiment was conducted with ten treatments (Table 1) in randomized block design (RBD) with three replications in plot of 3.0 m × 1.8 m each. Recommended dose of fertilizer (RDF) was applied @ 30:60:50 (N:P_2O_5:K_2O kg ha^{-1}) as fertilizer grade urea, single superphosphate (SSP) and muriate of potash (MOP), respectively. Three levels of B (1.0, 1.5 and 2.0 kg ha^{-1}) as borax and Zn (2.5, 5.O and 7.5 kg ha^{-1}) as zinc sulphate were applied as per treatments at seven days after basal application of NPK fertilizers. Seeds were sown on 2nd June 2013 and 2014 in well prepared flat bed at 45 cm row to row and 30 cm plant to plant spacing. The matured pods of seeds were harvested during 23rd August of 2013 and 27th August of 2014. Irrigation and intercultural operations like weed control and plant protection measures were adopted uniformly in each plot as and when required. In general, no incidence of disease and pest was recorded during both the season.

Table 1. Treatments undertaken in the experiment

T_1 (RDF)	: Recommended dose of fertilizer @ 30:60:50 (N:P_2O_5: K_2O kg ha^{-1})
T_2 (RDF+$B_{1.0}$)	: RDF+Boron @ 1.0 kg ha^{-1}
T_3 (RDF+$B_{1.5}$)	: RDF+Boron @ 1.5 kg ha^{-1}
T_4 (RDF+$B_{2.0}$)	: RDF+Boron @ 2.0 kg ha^{-1}
T_5 (RDF+$Zn_{2.5}$)	: RDF+Zinc @ 2.5 kg ha^{-1}
T_6 (RDF+$Zn_{5.0}$)	: RDF+Zinc @ 5.0 kg ha^{-1}
T_7 (RDF+$Zn_{7.5}$)	: RDF+Zinc @ 7.5 kg ha^{-1}
T_8 (RDF+$B_{1.0}$+$Zn_{2.5}$)	: RDF+Boron @ 1.0 kg ha^{-1}+Zinc 2.5 kg ha^{-1}
T_9 (RDF+$B_{1.5}$+$Zn_{5.0}$)	: RDF+Boron @ 1.5 kg ha^{-1}+Zinc @ 5 kg ha^{-1}
T_{10} (RDF+$B_{2.0}$+$Zn_{7.5}$)	: RDF+Boron @ 2.0 kg ha^{-1}+Zinc @ 7.5 kg ha^{-1}

Five plants were selected at random from the inner row of each plot at 60 days after sowing to determine the growth and its components. Plants were excised at ground level for separation into above ground (leaves, stem, and productive organs) and below ground portions (roots). The below ground portion was washed carefully under tap water and subsequently with distilled water. Leaves, stems, seeds and roots were oven dried at 70 °C for 72 h and their dry weights were measured. Plant height (cm), branches (number plant^{-1}), dry matter (g plant^{-1}), nodule dry weight (g plant^{-1}), pod length (cm), biological yield and seed yield (kg ha^{-1}) were recorded and harvested index was calculated. At harvest, the nutrient content on whole plant basis was also estimated to calculate nutrient uptake.

Soils and plants analysis

The soils from each plot were separately collected, air-dried, ground and passed through 2-mm size sieve for laboratory analysis. Soil samples were analyzed for OC by Walkley and Black method (Walkley and Black 1934), water holding capacity (WHC) using Keen Raczkowski box (Piper 1966), pH, available K (Jackon 1973) and available P (Bray and Kurtz 1945) before sowing the experimental crop and after the harvest of crop. The soil samples were extracted for available B (Wear 1965); the extract was treated with activated charcoal and estimated colorimetrically using azomethine-H method (Wolf 1971). Available Zn was extracted with DTPA-TEA (pH 7.3) (Lindsay and Norvell 1978) and estimated with the help of atomic absorption spectrophotometer (AAS, Model: ELCO-SL194). The plant samples of each plot were separately powdered in a stainless steel grinder. Dry powdered samples were ashed in a muffle furnace at 600 ºC and the ash was extracted in 10 mL of 0.36 *N* H_2SO_4 for 1 h at room temperature. The extract was used for determination of B colorimetrically using azomethine-H method (Gaines and Mitchell 1979) and Zn by AAS.

Statistical analysis

The statistical analysis of the data was carried out using STATISTICA (7.0) software.

Results and Discussion

Effect of nutrient management on growth and development

The data presented in table 2 revealed that growth of the plants was influenced by the treatments under study. Maximum plant height (average of two years) was observed under the treatment T_9 (RDF+$B_{1.5}$+$Zn_{5.0}$) (55.8 cm) which significantly differed from all other treatments at 5% level of significance. The second and third highest plant heights were observed under the treatments T_8 (RDF+$B_{1.0}$+$Zn_{2.5}$) (52.7 cm) and T_4 (RDF+$B_{2.0}$) (49.9 cm), respectively. Other treatments showed marginal increment of plant height as compared to T_1 (RDF). In case of other growth parameters (branches and dry matter per plant at 60 days), T_9 (RDF+$B_{1.5}$+$Zn_{5.0}$) showed significant effect as compared to other treatments which is in corroboration with the findings of Patel *et al*. (2011) and Mandal *et al*. (2009). However, critical observation revealed that most of the growth parameters did not differ significantly in both the years of experimentation. Nodules dry weight (g plant^{-1}) at 60 DAS showed that applied treatments influenced nodules production significantly (Table 2). Observation revealed that maximum average weight of nodules (5.2 g plant^{-1}) was recorded in treatment T_7 (RDF+$Zn_{7.5}$) and minimum in the treatment T_1 (RDF). This showed that nodule formation was greatly influenced by Zn application while B had little effect on nodule formation. Increase in the nodule weight in T_7 also increased the uptake of N by cowpea (Table 4). Similar finding was also reported by Agbenin *et al*. (1990) and Kishan *et al*. (2002).

Effect of nutrient management on yield attributes and seed yield

The longest pod length (33.6 cm) was observed under treatment T_4 (RDF+$B_{2.0}$) which significantly differed from all other treatments during both the years (Table 3). The shortest pod length (27.9 cm) was recorded under the RDF treatment (T_1). This indicates that application of B along with recommended dose of fertilizer greatly influenced the pod length of cowpea as compared to Zn. This corroborates with the findings of Singh *et al*. (2012) and Gogoi *et al*. (2016). Total biomass production was also influenced by different treatments (Table 3). The highest biological yield (3.45 t ha^{-1}) was recorded under the treatment T_9 (RDF+$B_{1.5}$+$Zn_{5.0}$) and the

Table 2. Growth of cowpea at 60 days as influenced by different treatments

Treatments	Plant height (cm)			Branches per plant			Dry matter (g plant^{-1})			Nodules dry weight (g plant^{-1})		
	2013	2014	Avg.	2013	2014	Avg.	2013	2014	Avg.	2013	2014	Avg.
T_1 (Control)	43.7	43.8	43.8	4.3	4.3	4.3	35.5	35.0	35.3	3.1	2.9	3.0
T_2 (RDF+$B_{1.0}$)	43.8	44.7	44.3	5.3	5.3	5.3	36.7	36.7	36.7	3.2	3.1	3.2
T_3 (RDF+$B_{1.5}$)	50.0	46.4	48.2	4.7	4.6	4.7	40.3	39.9	40.1	3.5	3.5	3.5
T_4 (RDF+$B_{2.0}$)	52.5	47.2	49.9	6.3	6.6	6.5	44.6	43.8	44.2	3.5	4.1	3.8
T_5 (RDF+$Zn_{2.5}$)	42.7	43.3	43.0	6.3	7.3	6.8	40.3	35.6	38.0	4.1	4.1	4.2
T_6 (RDF+$Zn_{5.0}$)	47.3	44.6	46.0	7.0	6.3	6.7	46.4	42.0	44.2	4.6	4.4	4.5
T_7 (RDF+$Zn_{7.5}$)	48.2	45.6	46.9	7.0	7.3	7.2	48.4	44.3	46.4	5.7	4.7	5.2
T_8 (RDF+$B_{1.0}$+$Zn_{2.0}$)	53.3	52.0	52.7	7.7	7.7	7.7	48.0	46.0	47.0	4.3	4.3	4.3
T_9 (RDF+$B_{1.5}$+$Zn_{5.0}$)	55.8	55.7	55.8	8.3	8.0	8.2	52.3	51.4	51.9	4.5	4.4	4.5
T_{10} (RDF+$B_{2.0}$+$Zn_{7.5}$)	46.3	45.6	46.0	7.7	7.6	7.7	45.7^{d}	44.4	45.1	4.4	4.0	4.2
SEm (±)	0.72	0.79	0.73	0.22	0.24	0.23	0.92	0.96	0.93	0.11	0.14	0.12
CD (P=0.05)	2.12	2.35	2.16	0.66	0.70	0.68	2.73	2.84	2.74	0.32	0.41	0.36

Table 3. Cowpea yield attribute and yield

Treatments	Pod length (cm)			Biological yield (t ha^{-1})			Seed yield (t ha^{-1})			Harvest index		
	2013	2014	Avg.	2013	2014	Avg.	2013	2014	Avg.	2013	2014	Avg.
T_1 (Control)	27.8	27.9	27.9	2.47	2.47	2.47	1.41	1.41	1.41	0.60	0.57	0.58
T_2 (RDF+$B_{1.0}$)	30.5	30.7	30.6	2.55	2.55	2.55	1.48	1.49	1.49	0.60	0.58	0.59
T_3 (RDF+$B_{1.5}$)	32.1	32.37	32.3	2.71	2.72	2.71	1.64	1.54	1.59	0.60	0.57	0.58
T_4 (RDF+$B_{2.0}$)	33.8	33.3	33.6	2.82	2.82	2.82	1.70	1.71	1.71	0.60	0.61	0.60
T_5 (RDF+$Zn_{2.5}$)	29.5	29.1	29.3	2.45	2.45	2.45	1.41	1.41	1.41	0.57	0.58	0.57
T_6 (RDF+$Zn_{5.0}$)	30.0	29.9	30.0	2.52	2.52	2.52	1.53	1.47	1.50	0.60	0.58	0.59
T_7 (RDF+$Zn_{7.5}$)	30.5	30.6	30.6	2.76	2.76	2.76	1.64	1.64	1.64	0.59	0.59	0.59
T_8 (RDF+$B_{1.0}$+$Zn_{2.0}$)	31.3	30.8	31.1	3.21	3.21	3.21	1.97	1.97	1.97	0.60	0.61	0.60
T_9 (RDF+$B_{1.5}$+$Zn_{5.0}$)	30.0	29.8	29.9	3.45	3.45	3.45	2.24	2.24	2.24	0.64	0.65	0.65
T_{10} (RDF+$B_{2.0}$+$Zn_{7.5}$)	31.1	30.7	30.9	3.16	3.16	3.16	1.89	1.89	1.89	0.60	0.58	0.59
SEm (±)	0.276	0.306	0.280	0.61	0.59	0.58	0.49	0.48	0.48	0.006	0.005	0.005
CD (P=0.05)	0.82	0.91	0.83	1.81	1.73	1.70	1.46	1.42	1.43	00.02	0.02	0.02

Table 4. Nutrient uptakes (kg ha^{-1}) by cowpea

Treatments	Nitrogen			Phosphorus			Potassium			Boron			Zinc		
	2013	2014	Avg.	2013	2014	Avg.	2013	2014	Avg.	2013	2014	Avg.	2013	2014	Avg.
T_1 (Control)	146.0	145.6	145.8	14.9	15.2	15.0	105.0	104.6	104.8	0.61	0.61	0.61	0.37	0.38	0.37
T_2 (RDF+$B_{1.0}$)	150.3	150.0	150.2	16.8	16.7	16.8	124.3	124.6	124.5	0.71	0.70	0.70	0.53	0.49	0.51
T_3 (RDF+$B_{1.5}$)	166.7	166.0	166.3	18.2	18.2	18.2	130.7	130.5	130.6	0.70	0.72	0.71	0.50	0.53	0.51
T_4 (RDF+$B_{2.0}$)	147.7	148.0	147.8	20.7	20.0	20.4	130.0	132.0	131.0	0.80	0.81	0.80	0.62	0.57	0.59
T_5 (RDF+$Zn_{2.5}$)	151.3	150.8	151.1	14.6	14.6	14.6	97.7	97.0	97.3	0.70	0.67	0.68	0.71	0.71	0.71
T_6 (RDF+$Zn_{5.0}$)	157.3	159.0	158.2	13.5	13.5	13.5	80.8	80.5	80.7	0.71	0.69	0.70	0.8	0.79	0.80
T_7 (RDF+$Zn_{7.5}$)	180.0	181.0	180.5	13.0	13.0	13.0	79.5	80.0	79.8	0.71	0.74	0.72	0.73	0.71	0.72
T_8 (RDF+$B_{1.0}$+$Zn_{2.0}$)	156.7	157.6	157.2	15.2	15.0	15.1	101.8	102.0	101.9	0.83	0.82	0.82	0.81	0.83	0.82
T_9 (RDF+$B_{1.5}$+$Zn_{5.0}$)	155.3	155.3	155.3	16.7	16.5	16.6	110.3	110.0	110.2	0.94	0.86	0.90	0.95	0.87	0.93
T_{10} (RDF+$B_{2.0}$+$Zn_{7.5}$)	157.3	154.6	156.0	16.3	16.1	16.2	109.0	108.3	108.7	0.71	0.74	0.70	0.76	0.72	0.74
SEm (±)	1.79	1.75	1.75	0.37	0.40	0.38	3.17	3.29	3.22	0.01	0.01	0.01	0.03	0.03	0.03
CD (P=0.05)	5.30	5.19	5.20	1.11	1.21	1.15	9.38	9.73	9.50	0.04	0.05	0.05	0.09	0.08	0.08

lowest (2.45 t ha^{-1}) under the treatment T_5 (RDF+$Zn_{2.5}$). However, close examination of data indicates that Zn and B gave synergic effect on the biological yield. This finding is in agreement with those of Ahlawat and Shivkumar (2005) and Banerjee *et al*. (2016). Cowpea seed yield was also found to be influenced by the treatments and maximum seed yield (2.24 t ha^{-1}) was recorded in the plot fertilized with treatment T_9 (RDF+$B_{1.5}$+$Zn_{5.0}$) which followed the same trend as in case of biological yield. Minimum harvest index (0.57) was observed under the treatment T_5 (RDF+$Zn_{2.5}$) whereas, maximum HI (0.65) was observed under the treatment T_9 (RDF+$B_{1.5}$+$Zn_{5.0}$) which remained at par with T_4 (RDF+$B_{2.0}$), T_7 (RDF+$Zn_{7.5}$) and T_8 (RDF+$B_{1.0}$+$Zn_{2.5}$). The findings obtained in this experiment are in agreement with those of Singh *et al*. (2012) and Moswatsi *et al*. (2013).

Effect of nutrient management on nutrient uptake by cowpea

Nitrogen uptake by cowpea was directly influenced with applied nutrients (Table 4). The highest uptake of N (180.5 kg ha^{-1}) was recorded in the treatment T_7 (RDF+$Zn_{7.5}$), whereas the lowest (145.8 kg ha^{-1}) was recorded with the treatment T_1 (RDF). The maximum uptake of P (20.4 kg ha^{-1}) and K (131.0 kg ha^{-1}) was registered in the treatment T_4 (RDF+$B_{2.0}$), however the lowest uptake of both P (13.5 kg ha^{-1}) and K (79.8 kg ha^{-1}) was noticed in the treatment of T_7. Similar uptake of P and K in soyabean was reported by Kamble and Deshpande (2014). In case of B and Zn uptake by cowpea, the highest amount (0.9 kg B ha^{-1} and 0.93 kg Zn ha^{-1}) was observed under the treatment T_9 (RDF+$B_{1.5}$+$Zn_{5.0}$), whereas, the lowest uptake (0.61 kg B ha^{-1} and 0.37 kg Zn ha^{-1}) was recorded with treatment T_1 (RDF). This indicates that higher uptake of B and Zn resulted maximum seed yield under the same treatments (Rama *et al*. 2015).

Effect of nutrient management in soil properties after harvest of cowpea

The data showed that none of the treatments significantly influenced the soil pH (Table 5).

Table 5. Soil properties after harvest of cowpea as influence by different treatments

Treatments	pH			Organic carbon (g kg^{-1})			WHC (%)			Avail. N (kg ha^{-1})			Avail. P_2O_5 (kg ha^{-1})			Avail-K_2O (kg ha^{-1})		
	2013	2014	Avg.	2013	2014	Avg.	2013	2014	Avg.	2013	2014	Avg.	2013	2014	Avg.	2013	2014	Avg.
T_1 (Control)	5.7	5.6	5.7	16.2	16.1	16.1	34.1	34.3	34.2	256	254	255	18.8	19.3	19.1	128.8	128.6	128.8
T_2 (RDF+$B_{1.0}$)	5.7	5.6	5.7	16.4	16.6	16.5	34.3	34.0	34.2	289	281	285	21.3	21.3	21.3	135.7	136.3	136.0
T_3 (RDF+$B_{1.5}$)	5.7	5.7	5.7	16.7	17.1	16.9	36.3	36.0	36.2	290	324	307	19.4	18.8	19.1	143.0	143.3	143.2
T_4 (RDF+$B_{2.0}$)	5.7	5.9	5.8	18.1	17.9	18.0	36.5	36.5	36.5	274	275	274	20.5	20.3	20.4	148.0	147.6	147.8
T_5 (RDF+$Zn_{2.5}$)	6.1	6.0	6.0	17.4	17.3	17.4	35.8	35.1	35.5	265	266	265	20.3	20.0	20.2	130.7	129.7	130.2
T_6 (RDF+$Zn_{5.0}$)	6.0	6.2	6.1	18.3	17.9	18.1	35.3	35.9	35.6	275	273	274	17.4	17.6	17.5	135.8	137.0	136.4
T_7 (RDF+$Zn_{7.5}$)	6.1	6.0	6.0	18.5	18.3	18.4	35.7	36.6	36.2	295	294	295	18.3	18.3	18.3	138.3	138.6	138.5
T_8 (RDF+$B_{1.0}$+$Zn_{2.0}$)	6.1	6.1	6.1	18.6	18.5	18.5	37.7	37.9	37.9	308	308	308	17.4	17.67	17.6	132.7	131.3	132.0
T_9 (RDF+$B_{1.5}$+$Zn_{5.0}$)	6.0	5.8	5.9	17.1	17.0	17.1	37.3	37.0	37.2	319	319	319	16.3	15.5	15.9	136.0	135.6	135.8
T_{10} (RDF+$B_{2.0}$+$Zn_{7.5}$)	6.0	5.6	5.9	17.3	17.4	17.3	35.5	35.2	35.4	268	300	284	15.2	14.6	15.0	129.5	129.0	129.3
SEm (±)	0.03	0.03	0.03	0.14	0.15	0.14	0.23	0.22	0.21	5.10	4.58	4.13	0.37	0.35	0.35	1.15	1.08	1.10
CD (P=0.05)	0.11	0.11	0.10	0.42	0.46	0.43	0.69	0.67	0.65	15.0	13.5	12.2	1.12	1.04	1.06	3.40	3.21	3.26

However, OC content and WHC of the soil were significantly influenced by the treatment combinations. The highest amount of OC (18.5 g kg^{-1}) and WHC (37.9%) were observed in the treatment T_8 (RDF+$B_{1.0}$+$Zn_{2.5}$). The lowest values were observed in the treatments T_1 (RDF) for both OC (16.1 g kg^{-1}) and WHC (34.2%). This corroborates with the findings of Sharma *et al*. (2016). There was significant build-up of available N and available K with the applied treatments. Maximum build-up of available N (319.7 kg ha^{-1}) was recorded under the treatment T_9 (RDF+$B_{1.5}$+$Zn_{5.0}$) which was at par with the treatments T_3 (RDF+$B_{1.5}$), T_7 (RDF+$Zn_{7.5}$) and T_8 (RDF+$B_{1.0}$+$Zn_{2.5}$) whereas maximum build-up of available K (147.8 kg ha^{-1}) was found under the treatments T_4 (RDF+$B_{2.0}$) which significantly differed from other treatments at 5% level of probability. Thus, the results indicate that both B and Zn significantly affected N availability in the soil, whereas available K expressed antagonistic effects when B and Zn were applied together. However, build-up of available P was drastically reduced with the application of B and Zn. This may be due to negative interaction of Zn, B and P on availability of soil P. Baboo and Mishra (2001) and Mandal *et al.* (2009) also reported similar trends of results with cowpea.

Conclusions

In the present investigation it was observed that the biological yield, seed yield and harvest index of cowpea were highest with application of boron @ 1.5 kg ha^{-1} and Zn @ 5.0 kg ha^{-1} along with recommended dose of NPK. This treatment also contributed significantly to improvement of nutrient availability in soil. Based on above findings, it may be concluded that nutrient management with recommended dose of NPK and micronutrients B (1.5 kg ha^{-1}) and Zn (5 kg ha^{-1}) can augment the economic yield of cowpea both in green pod and seed production as well as maintaining the soil health.

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References

Agbenin, J.O., Lombin, G. and Owonubi, J.J. (1990) Effect of boron and nitrogen fertilization on cowpea nodulation, mineral nutrition and grain yield. *Fertilizer Research* **22**, 71-78.

Ahlawat, I.P.S. and Shivakumar, B.G. (2005) *Kharif Pulses*. In *Textbook of Field Crops Production* (R. Prasad, Ed.) ICAR, New Delhi, India.

Ali, M. and Gupta, S. (2012) Carrying capacity of Indian Agriculture: pulse crops. *Current Science* **102**, 874-881.

Baboo, R. and Mishra, S.K. (2001) Growth and pod production of cowpea (*Vigna sinensis* L.) as affected by inoculation, nitrogen and phosphorus. *Annals of Agricultural Research* **22**,104-106.

Banerjee, H., Sarkar, S., Deb, P., Dutta, S.K., Ray, K., Rana. L. and Majumdar, K. (2016) Impact of fertilization on potato (*Solanum tuberosum* L.) yield, zinc use efficiency, quality and economics in Entisol of West Bengal. *Journal of the Indian Society of Soil Science* **64,** 176-182.

Bray, R.H. and Kurtz, L.T. (1945) Determination of total, organic and available form of phosphorus in soils. *Soil Science* **59**, 39-45

Das, D.K. (2003) *Micronutrients: Their Behavior in Soils and Plants*. Kalyani Publishers, New Delhi.

Debnath, P., Pattanaaik, S.K., Sah, D. and Pandey, A.K. (2015) Assessment of critical limit of boron for cowpea in piedmont soils of Arunachal Pradesh. *Archives of Agronomy and Soil Science,* doi.org/10.1080/03650340.2015.1019344.

Gaines, T.P. and Mitchell, G.A. (1979) Boron determination in plant tissue by the Azomethine H method. *Communications in Soil Science and Plant Analysis* **10,** 1099-1108.

Gogoi, N., Basumatary, A., Goswami, G., Hazarika, S., Bhattacharyya, D. and Medhi, B.K. (2016) Enrichment of rice grains with zinc through agronomic bio-fortification. *Journal of the Indian Society of Soil Science* **64**, 414-418.

Kamble, B.M. and Deshpande, A.N. (2014) Soil micronutrient and heavy metals status, uptake and yield of soybean-wheat cropping sequence as influenced by one time controlled application of primary treated biomethanated spentwash and chemical fertilizers. *Journal of the Indian Society of Soil Science* **62,** 391-397.

Kishan, S., Rathore, S.V.S. and Swaroop, K. (2002) Economics, nutrient content and pod yield of vegetable cowpea in relation to application of P, K and *Rhizobium* biofertilizer in Andaman. *Indian Agriculturist* **46**, 155-160.

Kumar, M., Jha, A.K., Hazarika, S., Verma, B.C., Choudhury, B.U., Ramesh,T., Moirangthem, P., Kumar, R., Brajendra., Rajkhowa., D.J., Kumar., A. and Devi, M.H. (2016) Micronutrient (B, Zn, Mo) for improving crop production on acid soils of Northeast India. *National Academy Science Letters* **39**, 85-89.

Lindsay, W.L. and Norvell, W.A. (1978) Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal* **42,** 421-428.

Mandal, M.K., Pati, R., Mukhopadhyay, D. and Majumdar, K. (2009) Maximizing yield of cowpea through soil test based nutrient application in Terai alluvial soils. *Better Crops* **3,** 28-30.

Moswatsi, M.S., Kutu, F.R. and Mafeo, T.P. (2013) Response of cowpea to variable rates and methods of zinc application under different field conditions. *African Crop Science Conference Proceedings* **11,** 757-762.

Ng, N.Q. and Marechal, R. (1985) Cowpea taxonomy, origin, germplasm. In *Cowpea Research Production and Utilization* (R.S. Singh and K.O. Rachie, Eds.), John Wiley and Sons, New York, pp. 11-22.

Padbhushan, R. and Kumar, D. (2014) Influence of soil and foliar applied boron on green gram in calcareous soils. *International Journal of Agriculture, Environment and Biotechnology* **7,** 129-136.

Patel, M.M., Patel, I.C., Patel, R.I. and Acharya, S. (2011) Effect of zinc and iron on yield and yield attributes of rainfed cowpea. *Annals of Arid Zone* **50**, 17-19.

Piper, C.S. (1966) *Soil and Plant Analysis*. Hans Publishers, Bombay, India.

Rama, L.C.S., Rao, P.C., Sreelatha,T., Padmaja, G. and Madhavi, R.P.V. (2015) Effect of integrated nutrient management on soil properties, yield and nutrient uptake in rice-green gram cropping system in an Inceptisol of Andhra Pradesh. *Journal of the Indian Society of Soil Science* **63,** 400-405.

Rattan, R.K., Patel, K.P., Manjaiah, K.M. and Datta, S.P. (2009) Micronutrients in soil, plant animal and human health. *Journal of the Indian Society of Soil Science* **57**, 546-558.

Sharma, K.S., Kapoor, S. and Rana, S.S. (2016) Effect of application of nitrogen, zinc and boron on soil properties and available nutrients status after the harvest of Wheat. *International Journal of Advances in Agricultural Science and Technology* **3**, 12-20.

Singh, A.K., Bhatt, B.P., Sundaram, P.K., Kumar, S., Bahrati, R.C., Chandra, N. and Rai, M. (2012) Study of site specific nutrient management of cowpea seed production and their effect on soil nutrient. *Journal of Agricultural Sciences* **4**, 191-198.

Wear, J.I. (1965) Boron. In *Methods of Soils Analysis* (C.A. Black, Ed.), **Part 2**. Agronomy 9. *American Society of Agronomy*, Madison, WI, pp. 1059-1063.

Wolf, B. (1971) The determination of boron in soil extracts, plant materials, compost, manures, water and nutrient solution. *Communications in Soil Science and Plant Analysis* **2**, 363-374.

Walkley, A. and Black, I.A. (1934) An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science* **37**, 29-38.

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