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Performance of zinc and boron on content, uptake of micronutrient and yield of cowpea (*Vigna unguiculata* Walp.) in Alfisols of Konkan region of Maharashtra

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Abstract

A field experiment was conducted at Research and Education Farm, Department of Agricultural Botany, College of Agriculture, Dapoli. The analytical work was carried out in the research laboratory of the Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dapoli on Alfiosls to study the effect of micronutrient cations on yield and their uptake by Cowpea (Vigna unguiculata Walp.) during rabi season of 2019-20. Cowpea crop responded significantly to B and Zn application over control. The highest seed yield (22.51 q ha^{-1}) and stover yield (33.50 q ha^{-1}) was obtained with 25:60:40 N:P_20_5:K_20 kg ha^{-1}(RDF) + Rhizobium and PSB @ 25g kg^{-1}seed + Boron @1.5 kg ha^{-1} + Zinc @ 7.5 kg ha^{-1} over control. The highest B, Fe, Mn, Zn and Cu content in stover at 45 days after sowing, in stoverat at harvest and seed was recorded in the treatment 25:60:40 N:P_20_5:K_20 kg ha^{-1}(RDF) + Rhizobium and PSB @ 25g kg^{-1}seed+ Boron @ 1.5 kg ha^{-1} + Zinc @ 7.5 kg ha^{-1}. The maximum uptake of B, Fe, Mn, Zn and Cu in stover, grain and their total was recorded in the treatment 25:60:40 N:P_20_5:K_20 kg ha^{-1}(RDF) + Rhizobium and PSB @ 25g kg^{-1}seed+ Boron @1.5 kg ha^{-1} + Zinc @ 7.5 kg ha^{-1}.The minimum uptake of B, Fe, Mn, Zn and Cu in stover, grain and their total was recorded in control.

Keywords: cowpea, yield, micronutrient content, micronutrient uptake

Introduction

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. Deficiency of micronutrients observed due to the intensive cropping with continuous use of high analysis micronutrient free chemical fertilizers, nonapplication of organic manures, and improper agronomic practices. This has become a limiting factor for high productivity of oil seed crops. Therefore, it is imperative to apply balanced micronutrients to deficient soil for high productivity of oil seed crops. Among the micronutrients, zinc and boron play an important role in legumes and oil seed crops productivity. Hence, a study was under taken to know the effect of zinc and boron application on micronutrient content and uptake by cowpea and the results obtained during the investigation are discussed.

Materials and Methods

A field experiment was conducted during *rabi* seasons of 2019-2020 at the Research and Education Farm, Department of Agricultural Botany, College of Agriculture, Dapoli. Soil was moderately acidic in reaction (pH 5.51), and having normal electrical conductivity (0.013 dSm^{-1}), moderately high in organic carbon (11.g kg^{-1}), low in available N (179.0 kg ha^{-1}) and very low and very high in available P_2O_5 (8.54 kg ha^{-1}) and available K_2O (383.0 kg ha^{-1}), respectively. The soil contained 33.86, 61.61, 0.23, 3.44 and 0.26 mg kg^{-1} DTPA, Fe, Mn, Zn Cu and B, respectively at the time of sowing. The plant nutrients were applied through fertilizer *viz*., urea, single super phosphate and muriate of potash for N, P and K, respectively. Along with this, FYM @ 5 t ha^{-1} was also used as the organic source of nutrient. The composition of FYM as well as inorganic fertilizers used in the present study is given in Table 1. For getting maximum yield of cowpea as well as for improving the soil health, application of N:P_2O_5:K_2O @ 25:60:40 kg ha^{-1} along with seed inoculation of *Rhizobium* and PSB @ 25g kg^{-1} seed during *rabi* season in lateritic soils of Konkan is recommended (Anonymous, 2014) [2]. The experiment was laid out in a randomized block design with eleven treatments replicated thrice.

The plant samples from individual treatmental plots were collected at 45 Days After Sowing (DAS) and after harvest and analyzed for nutrient concentrations, in order to evaluate the effect of treatments on yield and nutrient concentrations and uptakes. The details are presented in Table 2. For determination of micronutrients (Fe, Mn, Cu and Zn) 1.0 g plant sample was digested with di-acid mixture (HNO_3 + $HClO_4$) with the ratio 9**:**4 and acid extract was used for determination of micronutrients (Fe, Mn, Cu and Zn) (Singh *et al*., 1999) [17]. For determination of B, 0.5 g oven dry and finally ground plant sample was ignited gently to a white or gray ash in a porcelain evaporating dish in a muffle furnace at 550 ^{0}C. The dish and content were allowed to cool and extracted with 5 ml of 0.1N HCl and then by taking 1 ml of filtered aliquot, B in extract was determined by using spectrophotometer (Jackson, 1973) [7]. Micro-nutrient uptake (B, Fe, Mn, Cu and Zn uptake) was computed by multiplying the seed yield/stover yield in kg ha^{-1} with respective mg kg^{-1} nutrient content and product was divided by 1000. The uptake of nutrients by seed and stover were expressed as nutrient uptake by crop in g ha^{-1}. The nutrient uptake by seed and stover were summed up to express total nutrient uptake by crop in g ha^{-1}**.**

Results and Discussion

Yield (q ha^{-1})

The data regarding seed yield and Stover yield of cowpea as influenced by application of graded doses of B and Zn either alone or in combinations along with recommended dose of fertilizers *i.e.* 25**:**60**:**40 N**:**P_20_5**:**K_20 kg ha^{-1} + rhizobium and PSB @ 25g kg^{-1} seed varied from 10.56 to 22.51 q ha^{-1} and stover varied 16.74 to 33.50 q ha^{-1} (Table 3) indicating thereby that the Zn and B gave synergic effect on the biological yield. Treatment T_{11} (T_2 + B @ 2.0 kg ha^{-1} + Zn @ 7.5 kg ha^{-1}) registered the highest grain yield (33.50 q ha^{-1}) and Straw yield (33.50 q ha^{-1}), which was found to be at par with T_{10} and followed by T_9. These results suggest mutual synergism between Zn and B. Such synergistic effect of Zn and B on grain and straw yield of soybean was obtained by Malewar *et al.* (2001) [9], Bhagat *et al.*(2018) [3] and Goswami and Rama (2014) [6].

Micro-nutrient Content

Data pertaining to the content of B, Fe, Mn, Cu and Zn in stover of cowpea plant at flowering stage (45 DAS) and at harvest as well as seeds of cowpea as affected by the application of B and Zn have been presented in Table 4 and 5.

Boron Content (%)

Application of graded doses of B and Zn either alone or in combinations influenced the B content, which varied from 41.35 to 72.92 mg kg^{-1} in cowpea stover at flowering, 39.41 to 68.11 mg kg^{-1} in cowpea stover at harvest and 157.63 to 272.43 mg kg^{-1} in cowpea seed (Table 4).

Perusal of the data indicated that the application of graded doses of B and Zn either alone or in combinations (from treatment T_2 to T_{11}) significantly increased B content in plant and seed of cowpea over the absolute control *i.e.* no fertilizer application (T_1). The lowest values of B content *i.e.* 41.35 mg kg^{-1} in stover at 45 DAS, 39.41 mg kg^{-1} in stover at harvest and 157.63 mg kg^{-1} in seed were observed in control treatment (T_1) where RDF, B and/or Zn was not applied. Graded increase in B content in stover and seed was observed not only with the graded application of B, but with the graded application of Zn or combination of B + Zn also. However, the higher values of B content in stover and seed were obtained with the graded application of B only. Combined application of graded doses of B and Zn recorded the lower values than the sole B application. Significantly highest B content *i.e.* 72.92 mg kg^{-1} in stover at 45 DAS, 68.11 per cent in stover at harvest and 272.43 mg kg^{-1} in seed of cowpea was recorded in treatment T_5 (T_2 + B @ 2.00 kg ha^{-1}), which was found to be significantly superior over all other treatments and followed by treatment T_4 and T_{11}. B content in stover at 45 DAS and at harvest as well as B content in seed in descending order is as $T_5 > T_4 = T_{11} > T_{10} > T_3 > T_9 > T_8 > T_7 > T_6 > T_2 > T_1$.

The significant increase in B content in plant with the application of graded doses of B could be attributed to the direct addition of zinc through fertilizer to the available pool of the soil increasing availability of nutrients, which becomes available to the plants, resulting in higher uptake. The results of the present study are in agreement with those reported by Debnath *et al*. (2018) [5] in Inceptisols (pH 5.5) of Arunachal Pradesh. In sand culture studies, Mozafar (1989) [12] reported that with increasing B levels the concentration of plant nutrients were changed in the leaves as well as in the roots of maize plants. While, in soil studies, Miller and Smith (1977) [10] reported that applied B did not consistently affect the concentration of elements in tips, upper and lower leaves, upper and lower stem of alfalfa plants. It is clear from the reported conflicting statements of the investigators, that B effects on the behavior of nutrients vary depending on crop species or genotypes, plant part analyzed, various growth stages and the use of different types of growth media.

Iron Content (mg kg^{-1})

Application of graded doses of B and Zn either alone or in combinations influenced the Fe content, which varied from 432.12 to 470.70 mg kg^{-1} in cowpea stover at flowering, 399.49 to 446.63 mg kg^{-1} in cowpea stover at harvest and 173.97 to 231.26 mg kg^{-1} in cowpea seed (Table 4). Examination of the data indicated that the application of graded doses of B and Zn either alone or in combinations (from treatment T_2 to T_{11}) significantly increased Fe content in stover and seed of cowpea over the absolute control *i.e.* no fertilizer application (T_1). The lowest values of Fe content *i.e.* 432.12 mg kg^{-1} in stover at 45 DAS, 399.49 mg kg^{-1} in stover at harvest and 173.97 mg kg^{-1} in seed were observed in control treatment (T_1). Graded increase in Fe content in stover and seed was observed with the graded application of B or Zn, but, the higher values of Fe content in stover and seed were obtained with the combined graded application of B + Zn. Significantly highest Fe content *i.e.* 470.70 mg kg^{-1} in stover at 45 DAS, 446.63 mg kg^{-1} in stover at harvest and 231.26 mg kg^{-1} in seed of cowpea was recorded in treatment T_{11} (T_2 + B @ 2.00 + Zn @ 7.5 kg ha^{-1}), which was found to be at par with T_5, T_6, T_7, T_8, T_9 and T_{10} at 45 DAS and at harvest; while with T_6, T_7, T_8, T_9 and T_{10} in case of content in seed. The data revealed that the Fe content in stover showed decrease from flowering stage to harvest irrespective of different treatments. Patil (2010) [13] and Mhalshi (2014) [11] also observed decline in Fe concentration in plant with advancement of age. This may be attributed to the dilution effect of dry matter production. Boron usually becomes less available to plants with increase in pH (Das, 2007) [4]. The increase in the Fe content with higher levels of B and Zn may be due to increase in nutrients absorption resulting by more available nutrients in the soil solution and this probably promoted the well developed root system in upper zone. The results of the present study are in agreement with those reported by Debnath *et al*. (2018) [5] in Inceptisols (pH 5.5) of Arunachal Pradesh.

Manganese Content (mg kg^{-1})

Application of graded doses of B and Zn either alone or in combinations influenced the Mn content, which varied from 243.61 to 262.09 mg kg^{-1} in cowpea stover at flowering, 236.11 to 253.54 mg kg^{-1} in cowpea stover at harvest and 18.81 to 34.53 mg kg^{-1} in cowpea seed (Table 4). Assessment of the data indicated that the application of graded doses of B and Zn either alone or in combinations (from treatment T_2 to T_{11}) significantly increased Mn content in plant and seed of cowpea over the absolute control *i.e.* no fertilizer application (T_1). In this concern, Tisdale *et al*. (1995) [18] explained that neutral KCl applied to acid soils also can increase the Mn availability to plants and concentration in plants. The lowest values of Mn content *i.e.* 243.61 mg kg^{-1} in stover at 45 DAS, 236.11 mg kg^{-1} in stover at harvest and 18.81 mg kg^{-1} in seed were observed in control treatment (T_1) where RDF, B and/or Zn was not applied. Graded increase in Mn content in stover and seed was observed with the graded application of B or Zn, but, the higher values of Mn content in stover and seed were obtained with the combined graded application of B + Zn. Significantly highest Mn content *i.e.* 262.09 mg kg^{-1} in stover at 45 DAS, 253.54 mg kg^{-1} in stover at harvest was recorded in treatment T_{11} (T_2 + B @ 2.00 + Zn @ 7.5 kg ha^{-1}), which was found to be at par with all the treatments except T_1 at 45 DAS and with T_{10} at harvest. Treatment T_{10} (T_2 + B @ 2.00 + Zn @ 5.0 kg ha^{-1}) recorded the highest Mn content in seed of cowpea (34.53 mg kg^{-1}), which was at par with the treatments T_7, T_8, T_9 and T_{11}. The data revealed that the Mn content in stover showed decrease from flowering stage to harvest irrespective of different treatments. The probable reason behind decrease may be attributed to the dilution effect of dry matter production. The results of the present study are in agreement with those reported by Debnath *et al*. (2018) [5] in Inceptisols (pH 5.5) of Arunachal Pradesh. The Mn content values obtained in the present investigation are similar to those reported by Patil (2010) [13] and Mhalshi (2014) [11] in cowpea under lateritic soils.

Zinc Content (mg kg^{-1})

Application of graded doses of B and Zn either alone or in combinations influenced Zn content, which varied from 46.17 to 76.18 mg kg^{-1} in stover at flowering, 43.16 to 66.09 mg kg^{-1} in stover at harvest and 23.71 to 43.28 mg kg^{-1} in cowpea seed (Table 5). Zinc is less mobile as compared to P within the plant and therefore a large accumulation of Zn takes place in leaves, nodes and internodes. Appraisal of the data indicated that the application of graded doses of B and Zn either alone or in combinations (from treatment T_2 to T_{11}) significantly increased Zn content in plant and seed of cowpea over the absolute control *i.e.* no fertilizer application (T_1). The lowest values of Zn content *i.e.* 46.17 mg kg^{-1} in stover at 45 DAS, 43.16 mg kg^{-1} in stover at harvest and 23.71 mg kg^{-1} in seed were observed in control treatment (T_1) where RDF, B and/or Zn was not applied. Graded increase in Zn content in stover and seed was observed with the graded application of B or Zn, but, the higher values of Zn content in stover and seed were obtained with the combined graded application of B + Zn. Significantly highest Zn content *i.e*. 76.18 mg kg^{-1} in stover at 45 DAS, 66.09 mg kg^{-1} in stover at harvest and 43.28 mg kg^{-1} in seed of cowpea was recorded in treatment T_{11} (T_2 + B @ 2.00 + Zn @ 7.5 kg ha^{-1}), which was found to be at par with T_{10} at 45 DAS and T_7, T_8 and T_{10} at harvest and in seed. In remaining treatments, T_7, T_8 and T_9 at 45 DAS; T_4, T_5, T_6 and T_9 at harvest and T_5, T_6 and T_9 in seed were at par. The significant increase in Zn content in plant with the application of graded doses of Zn could be attributed to the direct addition of zinc through fertilizer to the available pool of the soil increasing availability of nutrients, which becomes available to the plants, resulting in higher uptake. The data revealed that the Zn content in stover showed decrease from flowering stage to harvest irrespective of different treatments. The trend observed in the present investigation can be substantiated by the fact that this may be attributed to the dilution effect of dry matter production. The results of the present study are in agreement with those reported by Debnath *et al*. (2018) [5] in Inceptisols (pH 5.5) of Arunachal Pradesh.

Copper Content (mg kg^{-1})

Application of graded doses of B and Zn either alone or in combinations influenced the Cu content, which varied from 0.92 to 2.76 mg kg^{-1} in stover at flowering, 0.81 to 2.61 mg kg^{-1} in stover at harvest and 0.71 to 2.50 mg kg^{-1} in cowpea seed (Table 5). Appraisal of the data indicated that the application of graded doses of B and Zn either alone or in combinations (from treatment T_2 to T_{11}) significantly increased Cu content in plant and seed of cowpea over the absolute control *i.e.* no fertilizer application (T_1). The lowest values of Mn content *i.e.* 0.92 mg kg^{-1} in stover at 45 DAS, 0.81 mg kg^{-1} in stover at harvest and 0.71 mg kg^{-1} in seed were observed in control treatment (T_1). Graded increase in Cu content in stover and seed was observed with the graded application of B or Zn, but, the higher values of Cu content in stover and seed were obtained with the combined graded application of B + Zn. Significantly highest Cu content *i.e.* 2.76 mg kg^{-1} in stover at 45 DAS, 2.61 mg kg^{-1} in stover at harvest and 2.50 mg kg^{-1} in seed of cowpea was recorded in treatment T_{11} (T_2 + B @ 2.00 + Zn @ 7.5 kg ha^{-1}), which was found to be at par with T_5, T_6, T_7, T_8, T_9 and T_{10} at 45 DAS and with T_4, T_5, T_6, T_7, T_8, T_9 and T_{10} at harvest and in seed. The Cu content in stover decreased at harvest as compared to stover at flowering stage. The decrease in Cu concentration in plants may arise from the dilution effect resulting from marked increase in plant growth. The results of the present study are in agreement with those reported by Debnath *et al*. (2018) [5] in Inceptisols (pH 5.5) of Arunachal Pradesh.

Effect of boron and zinc application on nutrient uptake by cowpea

Micro-nutrient Uptake

The uptake being closely related to total yield and contents of nutrients reflects consumption of nutrients by the crop from the soil at a particular yield level.

Boron Uptake (g ha^{-1})

As influenced by the application of graded doses of B and Zn either alone or in combinations, boron uptake varied from 99.31 to 270.16 g ha^{-1} by stover, 81.34 to 365.18 g ha^{-1} by seed and 180.65 to 635.34 g ha^{-1} total uptake by cowpea (Table 6). Appraisal of the data indicated that the application of graded doses of B and Zn either alone or in combinations (from treatment T_2 to T_{11}) significantly increased B uptake by plant and seed of cowpea over the absolute control *i.e.* no fertilizer application (T_1). Graded increase in B uptake by stover and seed was observed with the graded application of B (T_6 to T_8) which was followed by Zn (T_3 to T_5), but, the higher values of B uptake by stover and seed were obtained with the combined graded application of B + Zn (T_9 to T_{11}). The significant increase in B content in plant with the application of graded doses of B could be attributed to the direct addition of B through fertilizer to the available pool of the soil increasing availability of nutrients, besides; which becomes available to the plants, resulting in higher uptake. The lowest values of B uptake *i.e.* 99.31 g ha^{-1} by stover, 81.34 g ha^{-1} by seed and 180.65 g ha^{-1} of total B uptake by cowpea were observed in control treatment (T_1) where RDF, B and/or Zn was not applied. Graded increase in B uptake by stover and seed was observed with the graded application of B (T_3 to T_5), which was followed by Zn (T_6 to T_8), but, the higher values of B uptake by stover and seed were obtained with the combined graded application of B + Zn (T_9 to T_{11}). Significantly highest B uptake *i.e.* 270.16 g ha^{-1} by stover, 365.18 g ha^{-1} by seed and 635.34 g ha^{-1} total uptake by cowpea was recorded in treatment T_{11} (T_2 + B @ 2.00 + Zn @ 7.5 kg ha^{-1}), which was found to be at par with T_5 and T_{10} in case of stover uptake, T_5 in case of seed uptake and total uptake. The treatment difference between T_3, T_4, T_8 and T_9 in case of stover uptake; T_4 and T_{10} in case of seed uptake and total uptake were at par. The significant increase in B content in plant with the application of graded doses of B could be attributed to the direct addition of zinc through fertilizer to the available pool of the soil increasing availability of nutrients, which becomes available to the plants, resulting in higher uptake.The B uptake ranges reported here are in agreement with Rathod (2005) [14] and Rathod (2008) [15] in lateritic soils of Konkan.In this context, Lal and Rao (1954) [8] reported that B serves to regulate the accumulation of ions even from nutrient solutions. Similarly, Santra (1989) [16] reported that B not only functions within the plant, but also in the nutrient medium, thereby affecting the intake of nutrients.

Iron Uptake (g ha^{-1})

As influenced by the application of graded doses of B and Zn either alone or in combinations, iron uptake varied from 667.79 to 1496.03 g ha^{-1} by stover, 183.58 to 521.03 g ha^{-1} by seed and 851.37 to 2017.06 g ha^{-1} total uptake by cowpea (Table 6). Application of graded doses of B and Zn either alone or in combinations (from treatment T_2 to T_{11}) significantly increased Fe uptake content by stover and seed of cowpea over the absolute control i.e. no fertilizer application (T_1). The lowest values of Fe uptake *i.e.* 667.79 g ha^{-1} by stover, 183.58 g ha^{-1} by seed and 851.37 g ha^{-1} of total Fe uptake by cowpea were observed in control treatment (T_1) where RDF, B and/or Zn was not applied. Graded increase in Fe uptake by stover and seed was observed with the graded application of B (T_3 to T_5) and Zn (T_6 to T_8), but, the higher values of Fe uptake by stover and seed were obtained with the combined graded application of B + Zn (T_9 to T_{11}). Significantly highest Fe uptake *i.e.* 1496.03 g ha^{-1} by stover, 521.03 g ha^{-1} by seed and 2017.06 g ha^{-1} total uptake by cowpea was recorded in treatment T_{11} (T_2 + B @ 2.00 + Zn @ 7.5 kg ha^{-1}), which was found to be at par with T_9 and T_{10} in case of stover uptake and total uptake and T_{10} in case of seed uptake. The treatment difference between T_2, T_3, T_4, T_5, T_6, T_7 and T_8 in case of stover uptake; T_8 and T_9 in case of seed uptake and T_4, T_5, T_7 and T_8 in case of total uptake were at par. The Fe uptake ranges reported here are in agreement with Rathod (2005) [14] and Rathod (2008) [15] in lateritic soils of Konkan.

Manganese Uptake (g ha^{-1})

As influenced by the application of graded doses of B and Zn either alone or in combinations, manganese uptake varied from 394.73 to 848.70 g ha^{-1} by stover, 19.76 to 77.03 g ha^{-1} by seed and 414.48 to 925.72 g ha^{-1} total uptake by cowpea (Table 6). Application of graded doses of B and Zn either alone or in combinations (from treatment T_2 to T_{11}) significantly increased Mn uptake content by plant and seed of cowpea over the absolute control i.e. no fertilizer application (T_1). The lowest values of Mn uptake *i.e.* 394.73 g ha^{-1} by stover, 19.76 g ha^{-1} by seed and 414.48 g ha^{-1} of total Mn uptake by cowpea were observed in control treatment (T_1) where RDF, B and/or Zn was not applied. Graded increase in Mn uptake by stover and seed was observed with the graded application of B (T_3 to T_5) and Zn (T_6 to T_8), but, the higher values of Mn uptake by stover and seed were obtained with the combined graded application of B + Zn (T_9 to T_{11}). Significantly highest Mn uptake *i.e.* 848.70 g ha^{-1} by stover, 77.03 g ha^{-1} by seed and 925.72 g ha^{-1} total uptake by cowpea was recorded in treatment T_{11} (T_2 + B @ 2.00 + Zn @ 7.5 kg ha^{-1}), which was found to be at par with T_9 and T_{10} in case of stover uptake, seed uptake and total uptake. The treatment difference between T_2, T_3, T_4, T_5, T_6, T_7 and T_8 in case of stover uptake and total uptake and T_5, T_7 and T_8 in case of seed uptake were at par. The Mn uptake ranges reported here are in agreement with Rathod (2005) [14] and Rathod (2008) [15] in lateritic soils of Konkan.

Zinc Uptake (g ha^{-1})

As influenced by the application of graded doses of B and Zn either alone or in combinations, zinc uptake varied from 72.52 to 221.74 g ha^{-1} by stover, 24.88 to 97.28 g ha^{-1} by seed and 97.39 to 319.01 g ha^{-1} total uptake by cowpea (Table 7). Application of graded doses of B and Zn either alone or in combinations (from treatment T_2 to T_{11}) significantly increased Zn uptake

by stover and seed of cowpea over the absolute control *i.e.* no fertilizer application (T_1). Graded increase in Zn uptake by stover and seed was observed with the graded application of Zn (T_6 to T_8) which was followed by B (T_3 to T_5), but, the higher values of Zn uptake by stover and seed were obtained with the combined graded application of B + Zn (T_9 to T_{11}). The significant increase in Zn content in plant with the application of graded doses of Zn could be attributed to the direct addition of zinc through fertilizer to the available pool of the soil increasing availability of nutrients, which becomes available to the plants, resulting in higher uptake. Lowest values of Zn uptake *i.e.* 72.52 g ha^{-1} by stover, 24.88 g ha^{-1} by seed and 97.39 g ha^{-1} of total Zn uptake by cowpea were observed in control treatment (T_1) where RDF, B and/or Zn was not applied. Significantly highest Zn uptake *i.e.* 221.74 g ha^{-1} by stover, 97.28 g ha^{-1} by seed and 319.01 g ha^{-1} total uptake by cowpea was recorded in treatment T_{11} (T_2 + B @ 2.00 + Zn @ 7.5 kg ha^{-1}), which was found to be at par with T_9 and T_{10} in case of stover uptake, significantly superior in case of seed uptake and with T_{10} in case of total uptake. The treatment difference between T_4, T_5, T_6, T_7 and T_8 in case of stover uptake and T_8 and T_9 in case of seed uptake and total uptake were at par. The Zn uptake ranges reported here are in agreement with Rathod (2005) [14] and Rathod (2008) [15] in lateritic soils of Konkan.

Copper Uptake (g ha^{-1})

As influenced by the application of graded doses of B and Zn either alone or in combinations, copper uptake varied from 1.35 to 8.79 g ha^{-1} by stover, 0.74 to 5.63 g ha^{-1} by seed and 2.09 to 14.42 g ha^{-1} total uptake by cowpea (Table 7). Application of graded doses of B and Zn either alone or in combinations (from treatment T_2 to T_{11}) significantly increased Cu uptake content by stover and seed of cowpea over the absolute control *i.e.* no fertilizer application (T_1). Graded increase in Cu uptake by stover and seed was observed with the graded application of B (T_3 to T_5) and Zn (T_6 to T_8), but, the higher values of Cu uptake by stover and seed were obtained with the combined graded application of B + Zn (T_9 to T_{11}).

The lowest values of Cu uptake *i.e.* 1.35 g ha^{-1} by stover, 0.74 g ha^{-1} by seed and 2.09 g ha^{-1} of total Cu uptake by cowpea were observed in control treatment (T_1) where RDF, B and/or Zn was not applied. Significantly highest Cu uptake *i.e.* 8.79 g ha^{-1} by stover, 5.63 g ha^{-1} by seed and 14.42 g ha^{-1} total uptake by cowpea was recorded in treatment T_{11} (T_2 + B @ 2.00 + Zn @ 7.5 kg ha^{-1}), which was found to be at par with T_9 and T_{10} in case of stover uptake, seed uptake and total uptake. In remaining treatments, the treatment difference between T_3, T_4, T_5, T_6, T_7 and T_8 in case of stover uptake; T_5, T_7 and T_8 in case of seed uptake and T_4, T_5, T_7 and T_8 in case of total uptake were at par. The Cu uptake ranges reported here are in agreement with Rathod (2005) [14] and Rathod (2008) [15] in lateritic soils of Konkan.

Table 1: Nutrient composition of various inorganic fertilizers and FYM used in the study

Sr. No.	Name of fertilizer	Composition (%)				
		N	P2O5	K	B	Zn
1.	Urea	45.2	-	-	-	-
2.	Single super phosphate	-	15.4	-	-	-
3.	Muriate of potash	-	-	59.2	-	-
4.	Borax	-	-	-	11.34	-
5.	Zinc sulphate	-	-	-	-	21.0
6.	FYM	0.62	0.16	0.51	-	-

Table 2: Details of the treatments

Treat. No.	Description of Treatment
T_1	Absolute Control (No Fertilizers and Biofertilizers)
T_2	25:60:40 N:$P_2 0_5$:$K_2 0$ kg ha^{-1}(RDF) + Rhizobium and PSB @ 25g kg^{-1}seed
T_3	T2 + Boron @ 1.0 kg ha^{-1}
T_4	T2 + Boron @ 1.5 kg ha^{-1}
T_5	T2 + Boron @ 2.0 kg ha^{-1}
T_6	T2 + Zinc @ 2.5 kg ha^{-1}
T_7	T2 + Zinc @ 5.0 kg ha^{-1}
T_8	T2 + Zinc @ 7.5 kg ha^{-1}
T_9	T2 + Boron @ 1.0 kg ha^{-1}+ Zinc @ 2.5 kg ha^{-1}
T_10	T2 + Boron @1.5 kg ha^{-1}+ Zinc @ 5.0 kg ha^{-1}
T_{11}	T2 + Boron @1.5 kg ha^{-1} + Zinc @ 7.5 kg ha^{-1}

Table 3: Yield of cowpea as influenced by application of boron and zinc

Treat. No.	Description of Treatment	Seed Yield (q ha-1)	Stover Yield (q ha-1)
T_1	Absolute Control (No Fertilizers and Biofertilizers)	10.56	16.74
T_2	25:60:40 N:$P_2 0_5$:$K_2 0$ kg ha^{-1}(RDF) + Rhizobium and PSB @ 25g kg^{-1}seed	16.10	24.70
T_3	T2 + Boron @ 1.0 kg ha^{-1}	16.72	25.50
T_4	T2 + Boron @ 1.5 kg ha^{-1}	17.49	27.13
T_5	T2 + Boron @ 2.0 kg ha^{-1}	18.59	28.20
T_6	T2 + Zinc @ 2.5 kg ha^{-1}	15.14	24.50
T_7	T2 + Zinc @ 5.0 kg ha^{-1}	16.87	25.20
T_8	T2 + Zinc @ 7.5 kg ha^{-1}	19.14	27.60
T_9	T2 + Boron @ 1.0 kg ha^{-1}+ Zinc @ 2.5 kg ha^{-1}	20.79	31.60
T_10	T2 + Boron @1.5 kg ha^{-1}+ Zinc @ 5.0 kg ha^{-1}	21.67	32.10
T_{11}	T2 + Boron @1.5 kg ha^{-1} + Zinc @ 7.5 kg ha^{-1}	22.51	33.50
SE (m) ±		0.469	1.625
CD at 5%		1.382	4.793

Table 4: Boron, iron and manganese content in stover (mg kg^{-1}) at different growth stages and seed of cowpea as influenced by application of boron and zinc

Tr. No.		Boron (mg kg^{-1})			Iron (mg kg^{-1})			Manganese (mg kg^{-1})		
		Stover		Seed	Stover		Seed	Stover		Seed
		At 45 DAS	At harvest		At 45 DAS	At harvest		At 45 DAS	At harvest	
T1	Control (No NPK)	41.35	39.41	157.63	432.12	399.49	173.97	243.61	236.11	18.81
T2	25:60:40 N:P205:K20 kg ha^{-1} + Rhizobium and PSB @ 25g kg^{-1}seed	44.05	41.87	167.47	442.78	419.28	186.74	254.44	240.57	24.64
T3	T2 + B @ 1.0 kg ha^{-1}	54.88	51.71	206.83	446.91	414.51	197.19	256.48	241.20	26.26
T4	T2 + B @ 1.5 kg ha^{-1}	64.80	60.73	242.91	448.81	416.95	200.37	257.61	242.40	27.30
T5	T2 + B @ 2.0 kg ha^{-1}	72.92	68.11	272.43	452.12	425.82	205.27	258.53	243.66	29.21
T6	T2 + Zn @ 2.5 kg ha^{-1}	44.96	42.69	170.75	460.79	427.78	214.49	257.61	243.42	28.77
T7	T2 + Zn @ 5.0 kg ha^{-1}	46.76	44.33	177.31	463.42	429.77	218.10	258.94	245.24	30.32
T8	T2 + Zn @ 7.5 kg ha^{-1}	47.66	45.15	180.59	465.39	434.26	221.36	260.10	246.45	31.48
T9	T2 + B @ 1.0 kg ha^{-1} + Zn @ 2.5 kg ha^{-1}	51.27	48.43	193.71	466.34	439.54	225.20	260.09	248.09	32.78
T10	T2 + B @ 1.5 kg ha^{-1} + Zn @ 5.0 kg ha^{-1}	57.58	54.17	216.67	468.52	444.32	227.23	261.55	252.32	34.53
T11	T2 + B @ 2.0 kg ha^{-1} + Zn @ 7.5 kg ha^{-1}	64.80	60.73	242.91	470.70	446.63	231.26	262.09	253.54	34.17
	S.E±	2.090	1.900	7.601	7.161	7.23	7.384	2.779	1.662	1.783
	C.D (P=0.05)	6.166	5.605	22.422	21.126	21.329	21.783	8.199	4.902	5.261

Table 5: Zinc and copper content in stover (mg kg^{-1}) at different growth stages and seed of cowpea as influenced by application of boron and zinc

Tr. No.		Zinc (mg kg^{-1})			Copper (mg kg^{-1})		
		Stover		Seed	Stover		Seed
		At 45 DAS	At harvest		At 45 DAS	At harvest	
T1	Control (No NPK)	46.17	43.16	23.71	0.92	0.81	0.71
T2	25:60:40 N:P205:K20 kg ha^{-1} + Rhizobium and PSB @ 25g kg^{-1}seed	54.84	50.31	27.64	1.25	1.21	1.04
T3	T2 + B @ 1.0 kg ha^{-1}	60.29	54.33	29.74	2.25	2.19	1.14
T4	T2 + B @ 1.5 kg ha^{-1}	61.50	55.98	31.97	2.38	2.26	2.04
T5	T2 + B @ 2.0 kg ha^{-1}	62.92	56.81	33.51	2.45	2.40	2.13
T6	T2 + Zn @ 2.5 kg ha^{-1}	65.51	59.72	37.48	2.44	2.36	2.26
T7	T2 + Zn @ 5.0 kg ha^{-1}	68.51	63.02	39.11	2.46	2.41	2.30
T8	T2 + Zn @ 7.5 kg ha^{-1}	70.09	64.22	40.61	2.48	2.43	2.33
T9	T2 + B @ 1.0 kg ha^{-1} + Zn @ 2.5 kg ha^{-1}	71.76	60.57	38.21	2.54	2.42	2.41
T10	T2 + B @ 1.5 kg ha^{-1} + Zn @ 5.0 kg ha^{-1}	74.85	64.05	41.31	2.59	2.55	2.44
T11	T2 + B @ 2.0 kg ha^{-1} + Zn @ 7.5 kg ha^{-1}	76.18	66.09	43.28	2.76	2.61	2.50
	S.E±	1.419	1.744	1.459	0.112	0.144	0.161
	C.D (P=0.05)	4.187	5.146	4.303	0.331	0.425	0.474

Table 6: Boron, iron and manganese uptake by stover and seed of cowpea as influenced by application of boron and zinc

		Boron Uptake (g ha^{-1})			Iron Uptake (g ha^{-1})			Manganese Uptake (g ha^{-1})		
Tr. No.	Treatments	Stover	Seed	Total	Stover	Seed	Total	Stover	Seed	Total
T1	Control (No NPK)	99.31	81.34	180.65	667.79	183.58	851.37	394.73	19.76	414.48
T2	25:60:40 N:P205:K20 kg ha^{-1} + Rhizobium and PSB @ 25g kg^{-1}seed	152.61	140.97	293.58	1036.73	300.11	1336.85	594.03	39.57	633.61
T3	T2 + B @ 1.0 kg ha^{-1}	183.20	211.56	394.76	1055.87	329.09	1384.97	614.81	43.89	658.70
T4	T2 + B @ 1.5 kg ha^{-1}	219.41	285.22	504.63	1130.12	350.13	1480.24	657.62	47.86	705.48
T5	T2 + B @ 2.0 kg ha^{-1}	248.85	358.05	606.89	1202.13	381.83	1583.97	687.40	54.26	741.66
T6	T2 + Zn @ 2.5 kg ha^{-1}	153.92	137.44	291.36	1049.21	324.76	1373.97	596.46	43.52	639.97
T7	T2 + Zn @ 5.0 kg ha^{-1}	162.45	163.50	325.95	1081.87	368.49	1450.36	617.92	51.09	669.01
T8	T2 + Zn @ 7.5 kg ha^{-1}	180.18	191.92	372.10	1198.12	424.38	1622.51	680.09	60.05	740.13
T9	T2 + B @ 1.0 kg ha^{-1} + Zn @ 2.5 kg ha^{-1}	216.49	236.40	452.88	1388.47	468.18	1856.65	784.31	68.16	852.47
T10	T2 + B @ 1.5 kg ha^{-1} + Zn @ 5.0 kg ha^{-1}	238.34	296.16	534.49	1427.56	492.41	1919.97	810.59	74.82	885.41
T11	T2 + B @ 2.0 kg ha^{-1} + Zn @ 7.5 kg ha^{-1}	270.16	365.18	635.34	1496.03	521.03	2017.06	848.70	77.03	925.72
	S.E±	14.309	12.439	24.683	72.962	16.800	75.680	40.335	3.239	42.002
	C.D (P=0.05)	42.213	36.694	72.815	215.238	49.560	223.254	118.989	9.554	123.906

Table 7: Zinc and copper uptake by stover and seed of cowpea as influenced by application of boron and zinc

Tr. No.	Treatments	Zinc Uptake (g ha^{-1})			Copper Uptake (g ha^{-1})		
		Stover	Seed	Total	Stover	Seed	Total
T1	Control (No NPK)	72.52	24.88	97.39	1.35	0.74	2.09
T2	25:60:40 N:P205:K20 kg ha^{-1} + Rhizobium and PSB @ 25g kg^{-1}seed	123.76	44.51	168.26	3.03	1.69	4.72
T3	T2 + B @ 1.0 kg ha^{-1}	138.60	49.64	188.24	5.58	1.91	7.49
T4	T2 + B @ 1.5 kg ha^{-1}	151.97	55.87	207.83	6.13	3.56	9.69
T5	T2 + B @ 2.0 kg ha^{-1}	160.27	62.32	222.59	6.75	3.95	10.70
T6	T2 + Zn @ 2.5 kg ha^{-1}	146.06	56.72	202.77	5.81	3.42	9.24
T7	T2 + Zn @ 5.0 kg ha^{-1}	158.89	65.77	224.66	6.06	3.87	9.94
T8	T2 + Zn @ 7.5 kg ha^{-1}	177.34	77.47	254.80	6.72	4.46	11.18
T9	T2 + B @ 1.0 kg ha^{-1} + Zn @ 2.5 kg ha^{-1}	191.49	79.44	270.93	7.66	5.00	12.67
T10	T2 + B @ 1.5 kg ha^{-1} + Zn @ 5.0 kg ha^{-1}	205.16	89.52	294.68	8.11	5.29	13.40
T11	T2 + B @ 2.0 kg ha^{-1} + Zn @ 7.5 kg ha^{-1}	221.74	97.28	319.01	8.79	5.63	14.42
	S.E±	10.563	2.056	11.545	0.587	0.279	0.604
	C.D (P=0.05)	31.159	6.066	34.059	1.731	0.824	1.783

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