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Effect of different methods of Zn application on Zn, Fe, Cu and Mn concentration and uptake in some cowpea genotypes grown in mollisols of India

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Abstract

A pot experiment was conducted in the green house of GB Pant University of Agriculture and Technology Pantnagar, to study the effect of different methods of zinc application (soil application of 2.5 mg Zn kg^{-1} soil ($Zn_{2.5}$), soil application of 2.5 mg Zn kg^{-1} soil + foliar application of zinc ($Zn_{2.5 +F}$), no application of Zn (Zn_0) on zinc, copper, iron and manganese concentration in straw and grains and its uptake by twelve promising cowpea genotypes.

The main effect of genotypes and Zn levels had statistically significant influence on the average Zn concentration and its uptake in straw and grains of all cowpea genotypes. The main and interaction effect of zinc levels had no significant on copper concentration in grains and straw of all cowpea genotypes, whereas the significant increase in copper uptake was observed in grains of all cowpea genotypes with the soil application 2.5 mg Zn kg^{-1} soil and conjoint use of 2.5 mg Zn kg^{-1} soil and foliar application of zinc over no application of zinc. The main effect of zinc supply regimes showed that soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of 2.5 mg Zn kg^{-1} soil and foliar application of zinc had no statistically significant effect on average iron concentration in straw and grains while a significant increase in average iron uptake was observed in grains and straw of all cowpea genotypes, the interaction effect of genotypes and zinc supply regimes had statistically significant influence on average iron concentration in grains and straw of all cowpea genotypes. The main effect of soil application of Zn 2.5 mg kg^{-1} soil showed a significant increase in manganese concentration in grains of cowpea genotypes, while manganese concentration in grains was reduced with the conjoint use of soil application of Zn 2.5 mg Zn kg^{-1} soil and foliar application of Zn.

Keywords: Cowpea genotypes, Zn application methods and Zn, Fe, Cu, and Mn concentration and uptake

Introduction

Zinc plays a key role as a structural constituent or regulatory co-factor of a wide range of different enzymes and proteins in many important biochemical pathways and these are mainly concerned with: carbohydrate metabolism, both in photosynthesis and in the conversion of sugars to starch, protein metabolism, auxin (growth regulator) metabolism, pollen formation, the maintenance of the integrity of biological membranes, the resistance to infection by certain pathogens (Bhatt, *et al.*, 2019) [2]. The deficiency of Zn is one of the most important and prevalent deficiencies of micronutrients in the world causing decline in crop production and Zn malnutrition in animals and humans (Brown, 1993) [3].

In addition to alleviating the zinc deficiency with the zinc fertilization, zinc nutrition also influences the concentration of other nutrient elements in plant and soil system. Of the many interactions of Zn with other nutrients, the most widespread and important to crop production are those with N and P fertilizers on soils with limiting supplies of both Zn and N or P. Similar interactions of Zn with other essential nutrients will also be important on soils with low supplies of both nutrients; such an interaction of Zn with Cu was strongly enhanced by an effect of Zn in depressing Cu absorption and almost eliminating grain production in wheat when Cu was not applied. Other nutrients may interact with Zn by affecting its availability from soils and its status in the plant through the processes of growth or Zn absorption, distribution or utilization. In so doing, they may enhance or depress the response of plant growth to Zn (Loneragan and Webb, 1993) [10]. Similarly, the differential genotypic response under zinc application can be investigated. In view of these facts, a study was planned to evaluate the effect of different zinc application method on the concentration and uptake of Zn, Cu, Mn and Fe in some cowpea genotypes.

Material and Method

The pot experiment was conducted with a Typic Hapludol in plastic pots filled with 4 kg air dry soil during April 2014. The experimental soil was sandy loam in texture with pH 7.3, 0.53 percent organic carbon, 192.34 kg ha^{-1} alkaline $KMnO_4$ hydrolysable nitrogen, 18.72 kg ha^{-1} Olsen's phosphorus, 151.2 kg ha^{-1} ammonium acetate extractable potassium, DTPA extractable 0.81 mg Zn, 1.8 mg Cu, 36.6 mg Fe and 26.7 mg Mn kg^{-1} soil, respectively. The experiment was laid in a completely randomized design replicated thrice with three level of Zn, (0, soil application of 2.5 mg kg-1soil and soil application of 2.5 mg kg-1 + foliar application (0.5% Zn as ZnSO4). The foliar application of Zn was applied at preflowering and at poddling stage. The details of genotypes selected for study were V1= Pant Lobia-1 (IT 205-1), V2= Pant Lobia-2 (IT1042-3), V3 = Pant Lobia-3 (IT 889-1), V4 =IT ×IIII-1, V5 = PGCP 12 (IT 82E-18), V6 = PGCP 15(PL-10 K1-1-4-1-3), V7 = PGCP 16 (PGCP-5 × PGCP-1), V8= PGCP-31(PGCP-1 × PGCP-3-30), V9= PGCP-32(PGCP-3 × PGCP-6- 13), V10 = PGCP-33 (PGCP-8 × PGCP-22), V11= PGCP-34 (PGCP-12 × PGCP-4-17) and V12= PGCP-36(PGCP-12×N25-22). A basal dose of mg N, mg P and mg K @ 25:50:25 kg ha^{-1}was applied to each pot in solution form through urea, Dicalcium orthophosphate and potassium chloride. The pots were watered and left for equilibration. When the soil moisture was near to field capacity, six seeds were sown in each pot. After emergence, plants were thinned to three plants per pot. The pots were regularly watered as and when required. The maturing pods were collected for each pot separately in paper bags. At harvest, the plants were cut close to soil surface and separated into seed and straw. All samples were thoroughly washed in tap water, 0.1N HCl and finally in distilled water and dried in oven at 60^{o}C. The DTPA extractable Zn, Fe, Mn and Cu were determined in soil samples by using diethylene triamine penta acetic acid (DTPA) extraction procedure developed by Lindsay and Norvell (1978) [8].

Result and Discussion

Effect of soil application and conjoint use of soil application and foliar application of Zn on Zn concentration (mg Zn kg^{-1}) in seeds of cowpea genotypes

The data presented in table 1 indicated that the main effect of genotypes and Zn levels had statistically significant influence on the average Zn concentration in seeds of all cowpea genotypes. The lowest average Zn concentration in seeds was recorded in V7 (76.6 mg Zn kg^{-1}) while the average highest Zn concentration was noted in V10 (101.3 mg Zn kg^{-1}). Zinc concentration observed in seeds of V7 was at par with that of V1, V4, V6, V8 and V11. Further, Zn concentration in seeds of V10 was statistically similar to that of V12. As regard the main effect of Zn supply regimes, soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of 2.5 mg Zn kg^{-1} soil + foliar application of Zn increased the average Zn concentration in seed significantly by 30.9 and 57.3 percent over no application of Zn, respectively. The interaction effect of genotypes and Zn supply regimes had statistically significant effect on Zn concentration in seeds. All the cowpea genotypes except V4 and V9 showed significant increase in Zn concentration in seeds with the application of 2.5 mg Zn kg^{-1} soil in comparison to no application of Zn. The conjoint use of 2.5 mg Zn kg^{-1} soil + foliar application of Zn helped to further increase the concentration of Zn in seeds of all genotypes except V5 and V10 in comparison to soil application of 2.5 mg Zn kg^{-1} soil.

The concentration of zinc in seeds of cowpea genotypes increased significantly with the conjoint use of both soil and foliar application of Zn over soil application of 2.5 mg Zn kg^{-1} soil which might be attributed to more efficient use of foliar applied Zn by cowpea. Similar results were also reported by Yilmaz *et al*. (1997) [21] and Rengal *et al*. (1999) [15].

Effect of soil application and conjoint use of soil and foliar application of Zn on Zn concentration (mg Zn kg^{-1}) in straw

It is clearly evident from the data that the lowest average Zn concentration in straw was recorded in V3 (65.6 mg Zn kg^{-1}) while the highest average Zn concentration in straw was noted in V1 (98.1 mg Zn kg^{-1}). The Zn concentration observed in straw of V3 was at par with that of V2, V4, V5, V6, V7, V8, V9, V10 and V11 while the Zn concentration observed in straw of V1 was at par with that of V12.

As regard the main effect of Zn supply regimes, soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of 2.5 mg Zn kg^{-1} soil + foliar application of Zn increased the average Zn concentration in straw of all cowpea genotypes significantly by 40.2 and 325.9 percent over no application of Zn, respectively. The interaction effect of genotypes and Zn supply regimes also had statistically significant influence on Zn concentration in straw of all cowpea genotypes. Soil application of 2.5 mg Zn kg^{-1} soil increased the concentration of Zn in straw of only V6 genotype in comparison to no application of Zn. All the twelve genotypes showed significant increase in straw Zn concentration with conjoint use of 2.5 mg Zn kg^{-1} soil + foliar spray of Zn over no application of Zn.

Soil application of Zn was likely to increase the zinc concentration in soil solution for higher absorption of Zn from soil to consequently increase zinc content in seed and straw. These results also corroborated with the findings of Puniya *et al*. (2014) [14] who reported that soil, soil + single foliar, and soil + two foliar application of Zn increased the Zn concentration in straw significantly by 7.4, 14.3 and 18.89 percent over no application of Zn in mothbean, respectively.

Effect of soil application and conjoint use of soil and foliar application of Zn on uptake of Zn (µg Zn pot^{-1}) by seeds of cowpea genotypes

The main effect of genotypes and Zn levels had statistically significant effect on Zn uptake by seeds. The lowest average Zn uptake was recorded in seeds of V8 (74.2 µg Zn pot^{-1}) while the highest average Zn uptake in seeds was noted in V9 (412.1 µg Zn pot^{-1}). As regard the main effect of Zn supply regimes, soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of 2.5 mg Zn kg^{-1} soil + foliar application of Zn increased the average uptake of Zn in cowpea seeds significantly by 99.9 and 137.7 percent over no application of Zn, respectively. The interaction effect of genotypes and Zn supply regimes had statistically significant effect on Zn uptake in seeds. A close perusal of the data revealed that in case of genotypes V1, V2, V3, V4, V7 and V11, soil application of 2.5 mg Zn kg^{-1} soil brought a significant increase in Zn uptake in cowpea seed over no application of Zn. Soil application of 2.5 mg Zn kg^{-1} soil did not show any significant effect in increasing the uptake of Zn in seeds of V5, V6, V8, V9, V10 and V12 over no application of Zn. In case of genotypes V5, V6, V9, V10, V11 and V12, the conjoint soil and foliar application of Zn was more effective than soil application of 2.5 mg Zn kg^{-1} soil in increasing the Zn uptake in cowpea seeds.

The uptake of Zn by cowpea grains increased significantly with increasing Zn supply over no application of zinc mainly due to increase in Zn content in grains as a result of Zn application. Similar results were also reported by Singh and Ram (2001) [18]**.** Hart *et al*. (1998) [5] indicated that the rate of Zn uptake might be an important predictor of Zn efficiency. The increased Zn uptake in the seeds of V1, V2, V3, V4, V7 and V11 due to soil application of Zn might be attributed to the nature of its roots that might use soil applied Zn more effectively. However, an increase in Zn uptake in seeds of V5, V6, V9, V10, V11 and V12 due to conjoint application of zinc might be attributed to the fact that foliar spray of Zn helped to compensate lower utilization of soil applied Zn in their rooting zone. Oseni (2009) [12] also reported that Zn uptake by cowpea grain increased significantly with the increasing Zn application.

Effect of soil application and conjoint use of soil and foliar application of Zn on uptake of Zn (μg Zn pot^{-1}) by straw of cowpea genotypes

The data presented in table 1 showed that the lowest average Zn uptake in cowpea straw was recorded in V10 (336.9 μg Zn pot^{-1}) while the highest average Zn uptake in cowpea straw was noted in V1 (525.9 μg Zn pot^{-1}). The average Zn uptake in straw of V10 was at par with that of V3, V4, V5, V6, V7 and V11. The average Zn uptake in straw of V1 was at par with those of V8, V9 and V12. As regard the main effect of Zn levels, soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of 2.5 mg Zn kg^{-1} soil + foliar application of Zn increased the average Zn uptake in straw of all cowpea genotypes significantly by 75.4 and 426.0 percent over no application of Zn, respectively. The interaction effect of genotypes and Zn supply regimes had a statistically significant effect on zinc uptake by straw. A close perusal of data revealed that among all twelve cowpea genotypes, V2, V6 and V12 showed a significantly higher increase in Zn uptake by straw with the application of 2.5 mg Zn kg^{-1} soil over no application of Zn while conjoint soil and foliar application of Zn was found to be more effective in increasing the zinc uptake in straw of all cowpea genotypes over soil application of 2.5 mg Zn kg^{-1} soil and no application of Zn. Puniya *et al*. (2014) [14] also reported an increase in Zn uptake by straw with application of Zn.

Effect of soil application and conjoint use of soil and foliar application of Zn on total Zn uptake (μg Zn pot^{-1}) by cowpea genotypes

It is clearly evident from the data that the lowest average total Zn uptake in cowpea recorded in V5 (485.3 μg Zn pot^{-1}) while the highest average total uptake of Zn was noted in V9 (896.8 μg Zn pot^{-1}). The total Zn uptake noted in V5 was found at par with that of V3, V6, V8 and V10.

As regard the main effect of zinc supply regimes, soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of 2.5 mg Zn kg^{-1} soil + foliar spray increased the average total zinc uptake significantly by 85.3 and 305.8 percent over no application of zinc, respectively. The interaction effect of genotypes and zinc supply regimes had statistically significant effect on total Zn uptake by cowpea genotypes. A close perusal of data revealed that all twelve genotypes except V5 showed significant increase in total Zn uptake due application of 2.5 mg Zn kg^{-1} soil over no application of Zn. On the other hand, all cowpea genotypes showed significant increase in total Zn uptake with the conjoint use of 2.5 mg Zn kg^{-1} soil + foliar spray over no application of Zn. The conjoint application of Zn through soil and foliar spray was more effective in increasing total zinc uptake in all cowpea genotypes than soil application of 2.5 mg Zn kg^{-1} soil.

Total uptake is the function of nutrient content in seed and straw and their respective yield; Thereby, resulting into the significant increase in uptake of zinc. Similar increase in total Zn uptake under Zn treatment had observed in mothbean (Jain, 2007) [7] and in clusterbean (Sharma and Jain, 2004) [17]. In case of genotype V5 total Zn uptake was not increased with the soil application while it was increased significantly with combined use of soil + foliar application of Zn that might be attributed to better absorption of foliar applied Zn under the conditions where nutrient uptake and translocation from soil was restricted.

Effect of soil application and conjoint use of soil and foliar application of Zn on Cu concentration (mg Cu kg^{-1}) in seeds of cowpea genotypes

The data on Cu concentration (mg Cu kg^{-1}) in seeds of all twelve cowpea genotypes under varying zinc supply regimes are presented in Table 2.

As evident from the data presented in Table 2, the lowest average Cu concentration in seeds was recorded in V5 (4.4 mg Cu kg^{-1}) while the highest average Cu concentration in seeds was noted in V6 (9.1 mg Cu kg^{-1}). The average Cu concentration in seeds of V8 was at par with that of V5. The average Cu concentration in seeds of V6 was at par with that of V10. The main effect of zinc supply regimes and interaction effect of genotypes and zinc supply regimes had no statistically significant effect on Cu concentration in seeds of all cowpea genotypes.

An antagonistic effect between Zn and Cu had been reported earlier (Havlin *et al*., 2014 and Alloway, 2008) [6, 1]. However, in the present study, the magnitude of decrease brought in Cu concentration in cowpea seeds by Zn application was only lower and statistically not significant.

Effect of soil application and conjoint use of soil and foliar application of Zn on Cu concentration (mg Cu kg^{-1}) in straw of cowpea genotypes

It is clear from the data that the lowest average Cu concentration in straw was recorded in V8 (8.8 mg Cu kg^{-1}) while the highest average Cu concentration in straw was noted in V1 (15.7 mg Cu kg^{-1}). The average Cu concentration in straw of V8 was at par with that of V2, V3, V9 and V12. The main effect of zinc supply regimes had no had statistically significant influence on average Cu concentration in cowpea straw. The interaction effect of genotypes and Zn levels had no statistically significant effect on Cu concentration in cowpea straw.

Loneragan and Webb (1987) [9] reported that an antagonistic interactive effect was strongly enhanced by a decrease in Cu absorption and almost eliminated grain production in wheat if Cu was not applied. In the present study, the magnitude of decrease in Cu concentration with Zn supply was only minor which was statistically not significant. These results also corroborated with the findings of Poshtmasari *et al*. (2008) [13] who reported that application forms of Zn had no significant effects on Cu accumulation in seeds of common bean.

Effect of soil application and conjoint use of soil and foliar application of Zn on Cu uptake (μg Cu pot^{-1}) by seeds of cowpea genotypes

The data on Cu uptake (μg Cu pot^{-1}) by seeds of all twelve cowpea genotypes under varying zinc supply regimes are presented in Table 2, showed the lowest average Cu uptake in seeds was recorded in V8 (4.7 µg Cu pot^{-1}) while the highest average Cu uptake was noted in V9 (32.1 µg Cu pot^{-1}). The Cu uptake in seeds of V8 was at par with that of V5. As regard the main effect of zinc supply regimes, soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc increased the average Cu uptake in seeds of cowpea genotypes significantly by 59.3 and 46.4 percent over no application of zinc, respectively. The interaction effect of genotypes and zinc supply regimes had statistically significant influence on Cu uptake in seeds. A close perusal of data revealed that soil application of 2.5 mg Zn kg^{-1} soil brought a significant variation in Cu uptake in seeds of V1, V2, V4, V7 and V11 over no application of zinc while the conjoint use of both soil and foliar application of zinc in these genotypes either did not increase the Cu uptake in seeds or decreased it in comparison to the Cu uptake recorded under the soil application of 2.5 mg Zn kg^{-1} soil. In case of genotypes V5 and V6, the foliar application of zinc along with soil application of 2.5 mg Zn kg^{-1} soil was more effective than soil application of 2.5 mg Zn kg^{-1} soil in increasing the Cu uptake in seeds. In comparison to no application of Zn, conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of Zn increased Cu uptake in seeds of all cowpea genotypes except in the case of genotypes V3, V6, V8, V9 and V12.

A significant effect on average uptake of Cu by all cowpea genotypes with the application of soil and foliar application of Zn might be attributed to increase in seed yields of cowpea genotypes. Copper is essential component of superoxide dismutase (Cu-Zn-SOD) activity which stabilizes Cu-Zn SOD activity in plant and detoxify the superoxide radicals generated during photosynthesis. Fageria (2002) [4] also reported that application of Zn significantly improved uptake of copper in common bean.

Effect of soil application and conjoint use of soil and foliar application of Zn on Cu uptake (µg Cu pot^{-1}) by straw of cowpea genotypes

As apparent from the data, the lowest average Cu uptake in straw was recorded in V11 (48.5 µg Cu pot^{-1}) while the highest average Cu uptake was noted in V1 (82.9 µg Cu pot^{-1}). The Cu uptake recorded in straw of V11 was at par with that of V2, V3, V4, V8, V9 and V12. Similarly, the Cu uptake in straw recorded in V1 was at par with the values recorded in V6 and V7. The main effect of zinc supply regimes showed that soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc increased average the Cu uptake in straw significantly by 16.2 and 18.9 percent over no application of zinc, respectively. The interaction effect of genotypes and zinc supply regimes had no statistically significant impact on Cu uptake in straw.

The main effect of Zn supply regimes significantly increased the average Cu uptake by straw in all cowpea genotypes mainly by increasing straw yields. Similar results also obtained by Poshtmasari *et al.* (2008) [13] who reported maximum accumulation of Cu in leaves of common bean with the soil application of 40 mg Zn kg^{-1} soil.

Effect of soil application and conjoint use of soil and foliar application of Zn on total Cu uptake (µg Cu pot^{-1}) by cowpea genotypes

The data presented in table 2 reveal that the lowest average total Cu uptake was recorded in V8 (57.4 µg Cu pot^{-1}) while the highest average total Cu uptake was noted in V1 (99.9 µg Cu pot^{-1}). Total Cu uptake recorded in V8 was at par with that of V2, V3, V5 and V12. Similarly, total Cu uptake noted in V1 was at par with the values recorded in V6, V7 and V9. As regard the main effect of zinc supply regimes, soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc increased the average total Cu uptake significantly and equally by 23.7 percent over no application of Zn. The interaction effect of genotypes and zinc supply regimes had statistically significant influence on total Cu uptake. It is evident from the data that application of 2.5 mg Zn kg^{-1} soil brought a significant increase in total Cu uptake, in genotypes V1, V2 and V7 over no application of Zn while conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc did not increase the total Cu uptake or rather decreased it in comparison to the total Cu uptake noted under the soil application of 2.5 mg Zn kg^{-1} soil except in V9 where conjoint application of Zn increased total Cu uptake.

Soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil + foliar application of Zn had significant effect on increasing average total Cu uptake by cowpea genotypes due to increased yields without causing a significant decrease in Cu content of both seed and straw. Poshtmasari *et al.* (2008) [13] reported that Cu content in seeds of common bean were not differed with any application form of Zn.

Effect of soil application and conjoint use of soil and foliar application of Zn on Fe concentration (mg Fe kg^{-1}) in seeds of cowpea genotypes

The data on Fe concentration (mg Fe kg^{-1}) in seeds of all twelve cowpea genotypes under varying zinc supply regimes are presented in Table 3, showed the lowest average Fe concentration in seeds was recorded in V7 (30.3 mg Fe kg^{-1}) while the highest average Fe concentration in seeds was noted in V2 (48.4 mg Fe kg^{-1}). The average Fe concentration in seeds of V7 was at par with that of V3, V4, V6, V7, V8, V11 and V12. The average Fe concentration in V2 was at par with that of V5, V9 and V10. The main effect of zinc supply regimes showed that soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc had no statistically significant effect on average Fe concentration in seeds. Similar results were reported by Wei *et al.* (2012) [19] in rice. The interaction effect of genotypes and zinc supply regimes had statistically significant influence on Fe concentration in seeds. A close perusal of data revealed that soil application of 2.5 mg Zn kg^{-1} soil significantly increased Fe concentration in seeds of V7 over no application of zinc while conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc increased the Fe concentration in seeds of V2 but decreased it in V10 in comparison to the Fe concentration observed under no application of Zn.

Yadavi *et al.* (2014) [20] reported a significant increase in grain iron content with the foliar application of Zn. Poshtmasari *et al.* (2008) [13] also reported that the interaction effects between Zn rates and application forms showed a significant effect on Fe concentration in seeds and in their study the highest concentration of Fe in seed was observed in 40 mg Zn kg^{-1} soil treatment in comparison to seed pelleting treatment. However, the decrease in Fe concentration in seeds of cowpea genotypes might be due to the competitive effect between Zn and iron for the same absorption site and could retain iron in stems and roots, probably due to a competitive inhibition at the site of unloading from the xylem (Alloway, 2008) [1].

Effect of soil application and conjoint use of soil and foliar application of Zn on Fe concentration (mg Fe kg^{-1}) in straw of cowpea genotypes

It is clearly evident from the data that the lowest average Fe concentration in straw was recorded in V10 (209.8 mg Fe kg^{-1}) while the highest average Fe concentration in straw was noted in V12 (439.1 mg Fe kg^{-1}). The average Fe concentration in straw recorded in straw of V10 was at par with that of V5 and V9. The average Fe concentration in straw of V12 was at par with those observed in V1 and V8. The main effect of zinc supply regimes showed that soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc had no statistically significant effect on average Fe concentration in straw. The interaction effect of genotypes and zinc supply regimes had a statistically significant effect on Fe concentration in straw. The data revealed that in genotypes V7 and V12 soil application of 2.5 mg Zn kg^{-1} soil brought a significant increase in the Fe concentration in straw over no application of zinc while in the case of V2, V4 and V8 genotypes it decreased Fe concentration in straw in comparison to no application of Zn. The conjoint use of soil and foliar application of zinc increased the Fe concentration in straw in V1and V9 but decreased it in V7 and V11 in comparison to no application of Zn.

The decrease in Fe concentration in genotypes V2, V4 and V8 due to Zn application might be attributed to the fact that Zn strongly influences the iron metabolic function in plants (Poshtmasari *et al*. 2008) [13]. It has also been reported that the iron concentration in soil solution becomes comparatively low due to reduction in phyto-siderophores release if the optimum amount of Zn is present in soil solution (Alloway, 2008) [1]. Samreen *et al*. (2013) [16] also observed that like P, Zn application had an adverse effect on Fe contents in mungbean plants.

Effect of soil application and conjoint use of soil and foliar application of Zn on Fe uptake (µg Fe pot^{-1}) by seeds of cowpea genotypes

It is clearly evident from the data presented in table 3 that the lowest average Fe uptake in seeds was recorded in V8 (30.6 µg Fe pot^{-1}) while the highest average Fe uptake in seeds was noted in V9 (220.9 µg Fe pot^{-1}). The average Fe uptake recorded in seeds of V8 was at par with that of V6 and V12.The main effect of zinc supply regimes showed that soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc increased the average Fe uptake in seeds significantly by 56.7 and 66.8 percent over no application of zinc, respectively. The interaction effect of genotypes and zinc supply regimes had statistically significant effect on Fe uptake in seeds. The data revealed that soil application of 2.5 mg Zn kg^{-1} soil increased the Fe uptake in seeds significantly in the genotypes V1, V2, V4 and V7 over no application of zinc while conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc increased the Fe uptake in seeds in V1, V2, V4, V5, V7 and V11 in comparison to Fe uptake in seeds obtained under no application Zn. In general, conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc did not increase the uptake of Fe in seeds significantly over soil application of 2.5 mg Zn kg^{-1} soil except in V5 and V11 where conjoint application could significantly increase the uptake of Fe in seeds.

Fagaria *et al*. (2002) [4] also reported that with the increasing rate of Zn application there was no any definite trend in Fe content in seeds. However, the soil application of 40 mg Zn kg^{-1} soil was found superior to increase the iron uptake in seeds in comparison to 5, 10, 20, 80 and 120 mg Zn kg^{-1} soil rate of Zn application. On the other hand, Samreen *et al*. (2013) [16] also reported that Zn application had an adverse effect on Fe uptake in mungbean plants.

Effect of soil application and conjoint use of soil and foliar application of Zn on Fe uptake (µg Fe pot^{-1}) by straw of cowpea genotypes

It is clearly evident from the data that the lowest average Fe uptake in straw was recorded in V10 (935.2 µg Fe pot^{-1}) while the highest average Fe uptake in straw was noted in V12 (2591.4 µg Fe pot^{-1}). The Fe uptake recorded in straw of V10 was at par with that of V5 and V11. As regard the main effect of zinc supply regimes, soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc increased the average Fe uptake in straw significantly by 25.8 and 17.9 percent over no application of zinc, respectively. The interaction effect of genotypes and zinc supply regimes had statistically significant effect on Fe uptake in straw. A close perusal of data revealed that in case of genotypes V7 and V12, soil application of 2.5 mg Zn kg^{-1} soil brought significant increase in Fe uptake in straw over no application of Zn while the conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar spray of zinc increased the Fe uptake in straw significantly in V1, V3, V9 and V12 but decreased it in V6 in comparison no application Zn. Foliar spray of zinc along with soil application of 2.5 mg Zn kg^{-1} soil progressively increased the Fe uptake in straw in V1, V4, V8 and V9 in comparison to soil application of 2.5 mg Zn kg^{-1} soil. However, in genotypes V6, V7, V11 and V12, the conjoint application of Zn by soil and foliar application decreased the uptake of Fe by straw in comparison to the values obtained under soil application of 2.5 mg Zn kg^{-1} soil.

Significant effect on average iron uptake by cowpea straw was observed with soil application and conjoint use of soil + foliar application of Zn application could be ascribed to the increase in straw yields. On the contrary, Mohammad *et al*. (1990) [11] reported that Zn application did not affect Fe uptake in wheat straw.

Effect of soil application and conjoint use of soil and foliar application of Zn on total Fe uptake (µg Fe pot^{-1}) by cowpea genotypes

The data presented in table 3 clearly indicated that the lowest average total Fe uptake was recorded in V10 (1025.2 µg Fe pot^{-1}) while the highest average total Fe uptake was noted in V12 (2626.2 µg Fe pot^{-1}). The total Fe uptake recorded in V10 was at par with V5. Similarly, total Fe uptake recorded in V12 was at par with the values recorded in V8. The main effect of zinc supply regimes showed that soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc increased the average total Fe uptake significantly by 27.1 and 19.9 percent over no application of zinc, respectively. The interaction effect of genotypes and zinc supply regimes had statistically significant influence on total Fe uptake. A close perusal of data revealed that in genotypes V7 and V12, soil application of 2.5 mg Zn kg^{-1} soil brought significant increase in total Fe uptake over no application of zinc while the conjoint use of soil application of 2.5 mg Zn kg^{-1} soil + foliar application of zinc increased the total uptake of Fe only in V1, V3, V4 and V9 but decreased it in V6 in comparison to total Fe uptake observed under no application Zn. In comparison to soil application of Zn, the conjoint soil and foliar application of Zn decreased total Fe uptake in V7 but increased it in V8. Puniya *et al*. (2014) [14] also mentioned that the total uptake is the function of nutrient content in seed and straw and their respective yield thereby, resulting into a significant increase in uptake.

Effect of soil application and conjoint use of soil and foliar application of Zn on Mn concentration (mg Mn kg^{-1}) in seeds of cowpea genotypes

The data on Mn concentration (mg Mn kg^{-1}) in seeds of all twelve cowpea genotypes under varying zinc supply regimes are presented in Table 4.

It is clearly evident from the data that the lowest average Mn concentration in seeds was recorded in V3 (6.5 mg Mn kg^{-1}) while the highest average Mn concentration in seeds was noted in V11 (12.5 mg Mn kg^{-1}). The Mn concentration recorded in V3 was at par with that of V8. The main effect of zinc supply regimes showed that soil application of 2.5 mg Zn kg^{-1} soil increased the average Mn concentration in seeds significantly by 3.4 percent while the conjoint use of soil application of 2.5 mg Zn kg^{-1} soil + foliar application of zinc decreased the Mn concentration in seeds significantly by 6.4 percent over no application of zinc. The interaction effect of genotypes and zinc supply regimes failed to influence the Mn concentration in seeds significantly.

The observed significant increase in average Mn concentration in seeds of cowpea genotypes was observed with soil application of 2.5 mg Zn kg^{-1} soil while it was decreased with the additional supply of foliar spray of Zn suggesting that the supplement of Zn through soil application of 2.5 mg Zn kg^{-1} soil might be high enough to interfere in the transport mechanism of Mn for essential physiological function but further increase in Zn dosage beyond the soil application of 2.5 mg Zn kg^{-1} soil could reduce the average Mn concentration in seeds of cowpea. The interaction effect of genotypes and Zn supply regimes had no statistically significant effect on Mn concentration in seeds of cowpea genotypes. Poshtmasari *et al*. (2008) [13] reported that the Mn concentration in seeds of common beans was not affected with foliar spray of Zn.

Effect of soil application and conjoint use of soil and foliar application of Zn on Mn concentration (mg Mn kg^{-1}) in straw of cowpea genotypes

The data presented in table 4 clearly indicated that the lowest average Mn concentration in straw was recorded in V10 (57.8 mg Mn kg^{-1}) while the highest average Mn concentration (138.8 mg Mn kg^{-1}) in straw was noted in V8. The average Mn concentration in straw of V10 was at par with those observed in V3, V5 and V9. As regard the main effect of zinc supply regimes, soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of 2.5 mg Zn kg^{-1} and foliar application of zinc decreased the average Mn concentration significantly by 10.3 and 20.4 percent over no application of zinc, respectively. The interaction effect of genotypes and zinc supply regimes had statistically significant impact on Mn concentration in straw. A close perusal of data revealed that in case of genotypes V1 and V2, soil application of 2.5 mg Zn kg^{-1} brought a significant decrease in Mn concentration of straw over no application zinc while the conjoint use of soil application of 2.5 mg Zn kg^{-1} and foliar application of zinc decreased the Mn concentration in straw of V6 and V8 in comparison to Mn concentration of straw observed under no application Zn. The conjoint application of soil and foliar application decreased Mn concentration in straw of V6, V7 and V11 in comparison to the values obtained under soil application of 2.5 mg Zn kg^{-1} soil but a significant increase was recorded in V1 and V2.

The conjoint use of soil + foliar application of Zn had a significant effect on the average Mn concentration in cowpea straw. The significant increase in Mn concentration might be attributed to synergistic effect of Zn on Mn concentration in straw of cowpea genotypes. Similar results were also reported by Fageria (2002) [4]. The interaction effect of genotypes and Zn supply regimes on Mn concentration in straw of cowpea varied with genotypes. This might be due to complexicities in behaviour of different genotypes with respect to different micronutrients.

Effect of soil application and conjoint use of soil and foliar application of Zn on Mn uptake (µg Mn pot^{-1}) by seeds of cowpea genotypes

It is evident from the data that the lowest average Mn uptake was recorded in V8 (6.7 µg Mn pot^{-1}) while the highest average Mn uptake in seeds was noted in V9 (61.4 µg Mn pot^{-1}). The Mn uptake recorded in V8 was at par with that of V12.The main effect of zinc supply regimes indicated that soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of 2.5 mg Zn kg^{-1} and foliar application of zinc increased the average Mn uptake in cowpea seeds significantly by 68.8 and 44.7 percent over no application of zinc, respectively. The interaction effects of genotypes and zinc supply regimes had statistically significant effect on Mn uptake in seeds. The data revealed that in case of genotypes V1, V2, V4, V7, V9 and V11, soil application of 2.5 mg Zn kg^{-1} soil brought a significant increase in Mn uptake in seeds over no application of zinc while conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc increased the Mn uptake in seeds of V1, V2, V4, V5 and V7 in comparison to Mn uptake observed in seeds under no application Zn. In case of genotypes V1, V2, V3, V7 and V9, the conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc decreased the Mn uptake in comparison to values observed under soil application of 2.5 mg Zn kg^{-1} soil however, it increased the Mn uptake by seeds in V5 and V11. A significant increase in average Mn uptake in seeds of all twelve cowpea genotypes with the soil and combined use of soil + foliar application of zinc might be due to significant increase in seed yields. Similar results have been reported by Fageria (2002) [4] who concluded that in common bean plants, Mn addition had a significant and synergistic effect on Zn uptake. The increased uptake of Mn in case of genotypes V1, V2, V4, V7, V9 and V11 with the soil application of 2.5 mg Zn kg^{-1} soil over no application of Zn suggested a synergistic effect of Zn on supply of Mn from soil to plants in addition to yield increases brought by Zn application. Similarly, the conjoint use of soil + foliar application of Zn also increased the Mn uptake in seeds of genotypes V1, V2, V4, V5 and V7.

Effect of soil application and conjoint use of soil and foliar application of Zn on Mn uptake (µg Mn pot^{-1}) by straw of cowpea genotypes

As apparent from the data, the lowest average Mn uptake in straw was recorded in V10 (257.3 µg Mn pot^{-1}) while the highest average Mn uptake in straw was noted in V8 (818.9 µg Mn pot^{-1}). The Mn uptake in V10 was at par with that of V3, V5 and V11. The main effect of zinc supply regimes had no statistically significant impact on the average Mn uptake in straw of all twelve cowpea genotypes. The interaction effect of genotypes and zinc supply regimes had a statistically significant effect on Mn uptake in straw. The data revealed that soil application of 2.5 mg Zn kg^{-1} soil significantly increased the Mn uptake in straw of V7 over no application of zinc while the conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc increased the Mn uptake in straw in V9 but decreased it in V6 in comparison to Mn uptake in straw obtained under no application of Zn. Conjoint application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc progressively increased the Mn uptake in straw of V9 but decreased it in V6 and V7 in comparison to soil application of 2.5 mg Zn kg^{-1} soil.

It was observed that with the application of different Zn supply regimes all genotypes respond differently due to change in straw yields as well as Mn concentration in straw.

Effect of soil application and conjoint use of soil and foliar application of Zn on Total Mn uptake (µg Mn pot^{-1}) by cowpea genotypes by cowpea genotypes

The data presented in table 4 clearly indicate that the lowest average total Mn uptake was recorded in V10 (275.8 µg Mn pot^{-1}) while the highest average total Mn uptake was noted in V8 (825.5 µg Mn pot^{-1}). The average total Mn uptake recorded in V10 was at par with that of V3, V5 and V11. The main effect of zinc supply regimes had no statistically significant impact on the average total Mn uptake in all twelve cowpea genotypes. The interaction effect of genotypes and zinc supply regimes had a statistically significant effect on total Mn uptake. A close perusal of data revealed that soil application of 2.5 mg Zn kg^{-1} soil brought a significant increase in total Mn uptake over no application of zinc in V7 while conjoint use of both soil and foliar application of zinc increased the total Mn uptake in V9 but decreased it in V6 in comparison to total Mn uptake noted under no application Zn. In comparison to soil application of 2.5 mg Zn kg^{-1} soil, the conjoint use of soil application of 2.5 mg Zn kg^{-1} soil and foliar application of zinc progressively decreased the total uptake of Mn in V6 and V7 but increased it in V9.

The effect of Zn supply regimes on total Mn uptake of these cowpea genotypes could be attributed to the effect on seed and straw yields as well as Mn concentration in plant tissue.

Table 1: Effect of soil application and conjoint use of soil application and foliar application of Zn on Zn concentration and uptake in seeds and straw of cowpea genotypes

Genotypes	Zn concentration (mg Zn kg^{-1}) in seeds				Zn concentration (mg Zn kg^{-1}) in straw				Zn uptake (µg Zn pot^{-1}) by seeds				Zn uptake (µg Zn pot^{-1}) by straw				Total Zn uptake (µg Zn pot^{-1})			
	Zn_0	$Zn_{2.5}$	$Zn_{2.5+F}$	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5+F}$	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5+F}$	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5+F}$	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5+F}$	Mean
V1	59.2	82.8	99.1	80.4	50.1	56.8	187.3	98.1	35.5	331.6	200.1	189.1	227.6	336.5	1013.5	525.9	263.1	668.1	1213.6	714.9
V2	52.8	80.5	124.1	85.8	32.1	53.4	152.5	79.3	28.0	298.3	268.9	198.4	148.4	405.7	731.4	428.5	176.4	704.0	1000.2	626.9
V3	63.5	93.4	104.6	87.2	31.8	42.3	122.8	65.6	122.5	241.4	208.4	190.8	140.6	226.1	726.2	364.3	263.1	467.5	934.6	555.0
V4	74.0	76.6	88.2	79.6	29.4	34.4	166.6	76.8	104.8	331.6	309.8	248.7	114.3	155.6	895.2	388.4	219.2	487.3	1205.0	637.1
V5	73.3	93.3	100.2	88.9	41.8	52.2	128.3	74.1	75.7	52.1	247.4	125.1	185.2	227.1	668.3	360.2	260.9	279.2	915.7	485.3
V6	68.7	80.5	96.7	82.0	28.7	61.5	140.0	76.7	101.9	88.8	182.7	124.5	156.0	374.8	609.0	379.9	257.8	463.7	791.7	504.4
V7	59.2	71.9	98.8	76.6	35.3	38.0	162.3	78.5	105.6	247.0	301.8	218.1	146.3	244.9	827.7	406.3	251.9	491.9	1129.5	624.4
V8	58.2	82.2	96.6	79.0	35.1	46.0	144.6	75.2	63.3	70.5	88.9	74.2	185.9	275.5	960.2	473.8	249.1	345.9	1049.1	548.1
V9	72.4	74.6	106.4	84.5	26.6	34.5	152.4	71.1	351.4	394.2	490.7	412.1	135.4	192.8	1126.0	484.7	486.7	587.1	1616.6	896.8
V10	90.7	101.7	111.5	101.3	42.2	58.8	116.4	72.5	143.5	189.3	302.7	211.8	161.6	272.3	576.9	336.9	305.1	461.6	879.7	548.8
V11	55.8	80.3	97.0	77.7	25.9	46.7	149.7	74.1	149.4	310.8	410.5	290.2	93.2	182.8	742.3	339.4	242.6	493.6	1152.8	629.7
V12	60.4	114.1	116.4	97.0	37.9	59.6	151.5	83.0	56.2	108.0	167.7	110.6	176.3	387.1	962.8	508.8	232.5	495.2	1130.5	619.4
Mean	65.7	86.0	103.3	85.0	34.7	48.7	147.9	77.1	111.5	222.0	265.0	199.5	155.9	273.4	820.0	416.4	267.4	495.4	1084.9	615.9
Effect	V	Zn levels	V × Zn levels		V	Zn levels	V × Zn levels		V	Zn levels	V × Zn levels		V	Zn levels	V × Zn levels		V	Zn levels	V × Zn levels	
S.Em. ±	2.2	1.1	3.8		5.5	2.8	9.5		11.5	5.7	19.8		32.1	16.1	55.6		33.8	16.9	58.5	
C.D. ($p \leq 0.05$)	6.2	3.1	10.7		15.5	7.8	26.9		32.3	16.1	55.9		90.5	45.3	156.8		95.3	47.6	165.1	

Table 2: Effect of soil application and conjoint use of soil application and foliar application of Zn on Cu concentration and uptake in seeds and straw of cowpea genotypes

Genotypes	Cu concentration (mg Cu kg^{-1}) in seeds				Cu concentration (mg Cu kg^{-1}) in straw				Cu uptake (µg Cu pot^{-1}) by seeds				Cu uptake (µg Cu pot^{-1}) by straw				Total Cu uptake (µg Cu pot^{-1})			
	Zn_0	$Zn_{2.5}$	$Zn_{2.5+F}$	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5+F}$	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5+F}$	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5+F}$	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5+F}$	Mean
V1	8.8	7.5	7.7	8.0	15.9	16.2	15.0	15.7	5.3	30.3	15.5	17.0	73.9	94.5	80.4	82.9	79.2	124.7	95.9	99.9
V2	4.4	5.2	5.7	5.1	9.8	8.1	10.4	9.4	2.4	19.3	12.4	11.3	45.6	61.9	50.7	52.8	48.0	81.2	63.2	64.1
V3	5.4	5.6	5.1	5.4	9.9	10.3	12.6	10.9	10.4	14.6	10.3	11.8	43.4	55.2	74.3	57.6	53.8	69.8	84.6	69.4
V4	7.4	6.9	6.4	6.9	15.5	11.9	11.7	13.0	10.5	29.6	22.5	20.8	59.3	53.4	64.8	59.2	69.8	83.0	87.3	80.0
V5	4.4	4.2	4.7	4.4	13.1	14.9	12.1	13.4	4.6	2.3	11.6	6.2	57.9	64.4	63.9	62.1	62.5	66.8	75.5	68.3
V6	9.3	9.1	8.8	9.1	12.9	14.8	13.8	13.8	13.8	10.1	16.7	13.5	70.4	89.2	60.0	73.2	84.2	99.3	76.7	86.7
V7	7.3	8.8	8.6	8.2	12.9	14.0	15.1	14.0	13.3	30.2	26.7	23.4	53.8	90.4	77.0	73.7	67.0	120.6	103.7	97.1
V8	5.3	4.8	4.7	4.9	8.8	8.9	8.8	8.8	5.6	4.1	4.4	4.7	46.5	53.6	58.2	52.7	52.0	57.7	62.5	57.4
V9	7.0	6.3	6.4	6.6	10.7	8.1	10.0	9.6	34.0	33.1	29.1	32.1	54.5	45.9	74.4	58.2	88.5	79.0	103.4	90.3
V10	9.1	9.5	7.6	8.7	16.9	14.7	12.5	14.7	14.4	17.7	20.8	17.7	64.7	67.7	61.7	64.7	79.1	85.4	82.6	82.4
V11	7.5	6.7	6.4	6.9	13.4	9.9	11.7	11.7	20.1	26.4	27.1	24.5	48.3	39.7	57.5	48.5	68.4	66.1	84.6	73.0
V12	7.8	8.1	7.0	7.6	9.7	8.5	10.4	9.5	7.2	7.7	10.1	8.3	45.1	54.8	65.5	55.1	52.3	62.4	75.6	63.5
Mean	7.0	6.9	6.6	6.8	12.4	11.7	12.0	12.0	11.8	18.8	17.3	15.9	55.3	64.2	65.7	61.7	67.1	83.0	83.0	77.7
Effect	V	Zn levels	V × Zn levels		V	Zn levels	V × Zn levels		V	Zn levels	V × Zn levels		V	Zn levels	V × Zn levels		V	Zn levels	V × Z levels	
S.Em. ±	0.3	0.1	0.5		0.8	0.4	1.3		1.1	0.6	1.9		4.5	2.2	7.8		4.8	2.4	8.2	
C.D. ($p \leq 0.05$)	0.7	NS	NS		2.2	NS	NS		3.1	1.6	5.4		12.6	6.3	NS		13.4	6.7	23.2	

Table 3: Effect of soil application and conjoint use of soil application and foliar application of Zn on Fe concentration and uptake in seeds and straw of cowpea genotypes

Genotypes	Fe concentration (mg Fe kg^{-1}) in seeds				Fe concentration (mg Fe kg^{-1}) in straw				Fe uptake (µg Fe pot^{-1}) by seeds				Fe uptake (µg Fe pot^{-1}) by straw				Total Fe uptake (µg Fe pot^{-1})			
	Zn_0	$Zn_{2.5}$	$Zn_{2.5}$ + F	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5}$ + F	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5}$ + F	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5}$ + F	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5}$ + F	Mean
V1	34.6	39.7	40.4	38.2	387.5	351.8	472.7	404.0	20.8	159.6	81.2	87.2	1781.5	2078.4	2548.8	2136.2	1802.3	2238.0	2630.0	2223.4
V2	34.3	42.1	68.8	48.4	334.2	227.5	278.0	279.9	18.1	157.0	150.7	108.6	1519.5	1739.2	1311.7	1523.4	1537.6	1896.1	1462.3	1632.0
V3	36.4	31.6	34.9	34.3	281.3	279.7	306.5	289.1	69.7	87.1	69.7	75.5	1227.1	1471.8	1811.0	1503.3	1296.8	1558.9	1880.7	1578.8
V4	36.1	27.4	28.2	30.6	368.4	280.7	352.0	333.7	51.3	122.2	99.2	90.9	1434.5	1265.1	1904.5	1534.7	1485.8	1387.2	2003.8	1625.6
V5	39.6	47.2	46.4	44.4	257.8	208.5	202.1	222.8	41.3	26.2	114.1	60.5	1140.0	902.5	1067.3	1036.6	1181.3	928.7	1181.4	1097.1
V6	28.0	35.3	29.0	30.7	296.3	348.4	238.0	294.2	41.1	40.3	55.5	45.7	1620.6	2047.1	1036.0	1567.9	1661.8	2087.4	1091.5	1613.6
V7	21.1	35.5	34.3	30.3	340.7	439.2	254.2	344.7	37.1	122.3	105.9	88.4	1414.1	2837.9	1294.3	1848.7	1451.2	2960.2	1400.2	1937.2
V8	30.0	30.1	37.2	32.4	457.9	373.8	417.0	416.2	31.8	25.8	34.3	30.6	2419.1	2243.6	2771.5	2478.1	2450.9	2269.4	2805.7	2508.7
V9	48.0	38.0	49.9	45.3	202.1	214.8	334.1	250.3	231.9	201.2	229.6	220.9	1028.4	1225.5	2470.7	1574.9	1260.3	1426.7	2700.2	1795.7
V10	51.2	47.7	36.2	45.0	207.8	261.4	160.2	209.8	81.8	89.0	99.2	90.0	797.2	1197.0	811.4	935.2	879.0	1286.0	910.7	1025.2
V11	37.4	30.5	38.1	35.3	308.8	373.3	196.7	292.9	99.1	114.8	160.9	124.9	1108.1	1543.3	976.4	1209.3	1207.1	1658.1	1137.3	1334.2
V12	27.4	30.5	34.1	30.7	408.7	511.4	397.1	439.1	25.5	29.4	49.7	34.8	1912.8	3341.7	2519.6	2591.4	1938.3	3371.1	2569.2	2626.2
Mean	35.3	36.3	39.8	37.1	321.0	322.5	300.7	314.7	62.5	97.9	104.2	88.2	1450.2	1824.4	1710.2	1661.6	1512.7	1922.3	1814.4	1749.8
Effect	V Zn levels V × Zn levels				V Zn levels V × Zn levels				V Zn levels V × Zn levels				V Zn levels V × Zn levels				V Zn levels V × Zn levels			
S.Em. ±	2.8	1.4	4.8		14.9	7.5	25.8		9.6	4.7	16.2		102.0	51.0	176.7		102.2	51.1	177.1	
C.D. ($p \leq 0.05$)	7.9	NS	13.6		42.0	NS	72.8		26.4	13.2	45.7		287.6	143.8	498.2		288.2	144.1	499.2	

Table 4: Effect of soil application and conjoint use of soil application and foliar application of Zn on Mn concentration and uptake in seeds and straw of cowpea genotypes

Genotypes	Mn concentration (mg Mn kg^{-1}) in seeds				Mn concentration (mg Mn kg^{-1}) in straw				Mn uptake (µg Mn pot^{-1}) by seeds				Mn uptake (µg Mn pot^{-1}) by straw				Total Mn uptake (µg Fe pot^{-1})			
	Zn_0	$Zn_{2.5}$	$Zn_{2.5}$ + F	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5}$ + F	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5}$ + F	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5}$ + F	Mean	Zn_0	$Zn_{2.5}$	$Zn_{2.5}$ + F	Mean
V1	10.5	9.9	8.4	9.6	133.4	80.9	117.4	110.6	6.3	39.2	17.0	20.8	608.4	486.1	636.5	577.0	614.7	525.3	653.5	597.8
V2	9.6	11.1	10.3	10.3	102.3	52.2	87.6	80.7	5.1	41.0	22.1	22.7	468.2	397.8	411.8	425.9	473.3	438.8	433.9	448.7
V3	6.7	7.7	5.2	6.5	69.3	56.5	78.3	68.0	13.0	19.9	10.4	14.4	318.1	312.4	472.3	367.6	331.0	332.2	482.7	382.0
V4	12.2	10.8	9.6	10.9	108.9	83.4	72.3	88.2	17.3	47.0	33.6	32.6	425.8	375.7	391.6	397.7	443.1	422.7	425.2	430.4
V5	9.1	10.5	10.4	10.0	66.4	62.1	52.5	60.3	9.3	5.8	25.6	13.6	296.1	268.1	278.4	280.9	305.4	273.9	304.0	294.5
V6	9.0	8.9	9.8	9.2	106.3	103.3	67.1	92.2	13.3	9.8	18.3	13.8	584.4	595.1	291.5	490.3	597.6	604.9	309.8	504.1
V7	10.0	10.0	8.6	9.5	113.4	134.4	82.7	110.2	17.8	34.1	26.0	26.0	469.8	865.2	416.5	583.8	487.6	899.3	442.6	609.8
V8	7.4	7.0	6.6	7.0	156.1	143.6	116.6	138.8	7.9	6.0	6.1	6.7	825.7	855.4	775.5	818.9	833.6	861.3	781.6	825.5
V9	12.5	13.1	11.7	12.5	62.8	53.4	74.0	63.4	60.8	69.2	54.1	61.4	320.5	301.2	547.1	389.6	381.3	370.4	601.2	451.0
V10	9.6	10.1	8.1	9.3	56.1	73.1	44.3	57.8	14.9	18.7	21.9	18.5	214.8	336.0	221.0	257.3	229.7	354.7	242.9	275.8
V11	13.8	14.4	13.2	13.8	84.6	101.9	56.3	80.9	37.1	56.3	55.7	49.7	307.9	417.4	281.1	335.5	345.0	473.7	336.8	385.1
V12	8.9	10.1	9.9	9.6	124.3	117.0	93.3	111.5	8.3	9.5	14.4	10.7	585.6	766.0	586.2	645.9	593.9	775.5	600.6	656.7
Mean	10.0	10.3	9.3	9.8	98.7	88.5	78.5	88.5	17.6	29.7	25.4	24.2	452.1	498.0	442.5	464.2	469.7	527.7	467.9	488.4
Effect	V Zn levels V × Zn levels				V Zn levels V × Zn levels				V Zn levels V × Z levels				V Zn levels V × Zn levels				V Zn levelsV × Zn levels			
S.Em. ±	0.4	0.2	0.7		7.1	3.6	12.3		1.5	0.8	2.6		42.4	21.2	73.5		42.5	21.2	73.5	
C.D. ($p \leq 0.05$)	1.2	0.6	NS		20.1	10.0	34.7		4.3	2.1	7.4		119.6	NS	207.1		119.7	NS	207.4	

Conclusion

All the genotypes responded differently with the different zinc supply regimes. Soil application of 2.5 mg Zn kg^{-1} soil and conjoint use of soil application of 2.5 mg Zn kg^{-1} soil + foliar application of Zn increased Zn concentration in seed and straw significantly over no application of Zn. Soil application of Zn and conjoint use of Zn through soil and foliar application had significant influence on Zn and Mn concentration and uptake of micronutrients cations in seeds and straw of all cowpea genotypes. The interaction effect of genotypes and Zn supply regimes influenced the concentration and uptake of micronutrient cations.

References

1. Alloway BJ**.** Zinc in Soils and Crop Nutrition. Edn 2,. IZA and IFA Brussels, Belgium and peris, France 2008,1-135.
1. Bhatt SC, Rawat D, Srivastava PC**.** Effect of Zn Application on Root Growth Parameters and Shoot Dry Matter Content of Some Cowpea Genotypes. Int. J Curr. Microbiol. App. Sci 2019;8(04):1338-1349.
2. Brown PH, Cakmak I, Zhang Q. Form and Function of Zinc in Plants. In: Zinc in Soils and Plants, Edn Robson, A.D. (Ed.). Kluwer Academic Publishers, Dord Recht. Australia 1993;1(55):90-106.
3. Fageria NK. Influence of micronutrients on dry matter yield and interaction with other nutrients in annual crops. Pesquisa Agropecuaria Brasileira 2002;37(12):1765-1772.
4. Hart JJ, Norvell RM, Welch, LA, Sullivan, Kochian LV**.** Characterization of Zinc uptake, binding and translocation in intact seedlings of bread and durum wheat cultivars. Plant Physiology 1998;118:219-226.
5. Havlin JL, Tisdale SL, Nelson WL, Beaton JD. Soil Fertility and Fertilizers - An Introduction to Nutrient Management, Edn 8. Pearson Education Inc. New Jersey, U.S.A. 2014,273.
6. Jain AK, Kumar S, Panwar JDS**.** Response of mungbean (*Vigna radiata*) to phosphorus and micronutrients on

nitrogen and phosphorus uptake and seed quality. Legume Research 2007;30**:**201-204.

7. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Science Society of American Journal 1978;42**:**421-428.
8. Loneragan JF, Webb MJ**.** Translocation and function of zinc in roots. Journal of Plant Nutrition 1987;10:1247–1254.
9. Loneragan JF Webb MJ. Interactions between zinc and other nutrients affecting the growth of plants. Edn 1, Vol 55, Robson, A.D. (Ed.). Kluwer Academic Publishers, DordRecht. Australia 1993,119-131.
10. Mohammad W, Iqbal MM, Shah SM. Effect of mode of application of zinc and iron on yield of wheat. *Sarhad* Journal of Agriculture 1990;6(6):615-618.
11. Oseni TO. Growth and zinc uptake of sorghum and cowpea in response to phosphorus and zinc fertilization. World Journal of Agricultural Sciences 2009;5(6):670-674.
12. Poshtmasari HK, Bahmanyar MA, Pirdashti H, Shad MAA**.** Effects of zinc rates and application forms on protein and some micronutrient accumulation in common Beans (*Phaseolus vulgaris* L.). Pakistan journal of Biological Sciences 2008;11(7):1042-1046.
13. Puniya MM, Shivran AC, Khangarot SS, Kuri BR, Choudhary SP. Effect of phosphorus and zinc fertilization on productivity and nutrient uptake of mothbean. Annals of Agricultural Research 2014;35(1):58-61
14. Rengal Z, Batten GD, Crowley DE. Agronomic approaches for improving the micronutrient density in edible portions of field crops. Field Crops Research 1999;60:27-40.
15. Samreen T, Humaria Shah HU, Ullah S, Javid M. Zinc effect on growth rate, chlorophyll, protein and mineral contents of hydroponically grown mung beans plant (*Vigna radiata*). Arabian Journal of Chemistry http://dx.doi.org/10.1016/j.arabjc.2013.07.005
16. Sharma K, Jain KK. Effect of zinc and thiourea on growth, yield and quality of cluster bean. Annals of Agricultural Research 2004;25:169-171.
17. Singh AK, Ram H. Effect of phosphorus and zinc on yield and quality of mungbean. Annals of Plant and Soil Research 2001;3(2):307-309.
18. Wei Y, Shohag MJI, Yang X. Biofortification and bioavailability of rice grain zinc as affected by different forms of foliar zinc fertilization. PLoS ONE 2012;7(9):e45428. doi:10.1371/journal.pone.0045428
19. Yadavi A, Aboueshaghi RS, Dehnavi, MM. Balouchi H. Effect of micronutrient foliar application on grain qualitative characteristics and some physiological traits of bean (*Phaseolus vulgaris* L.) under drought stress. Indian Journal of Fundamental and Applied Life Sciences 2014;4(4):124-131
20. Yilmaz A, Ekiz H, Tourn B, Gultekin I, Karanlik S, Bagci SA, Cakmak I. Effect of different zinc application methods on grain yield and zinc concentration in wheat grown on zinc-deficient calcareous soils. Central Anatolia Journal of Plant Nutrition 1997;20:461-471.