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Evaluation of Zinc and Iron Availabilities in Soils of Selected Areas of Ethiopia for Haricot Bean Production under Greenhouse Condition

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Abstract

The availability of zinc and iron in soils of Kontela, Taba, Jole Andegna, Tenkaka Umbulo, Alage and Huletegna Choroko was not evaluated for production of Haricot bean. Therefore, this study was conducted to verify the results of laboratory analysis for micronutrients and evaluate the availability of zinc and iron in the above soils for haricot bean production. A greenhouse experiment was conducted in soils collected from the above sites using the following treatments: (1) no fertilizer (2) application of N and P; (3) application of N, P and Zn; (4) application of N, P, and Fe; (5) application of N, P, Zn and Fe (6) application of Zn only; (7) application of Fe only. Sources of Zn, iron, N and P were zinc sulfate heptahydrate ($ZnSO_4.7H_2O$ (21% Zn)), iron sulfate heptahydrate ($FeSO_4.7H_2O$ (20% Fe)), urea and TSP, respectively. Haricot bean variety Nasir was planted in a pot filled with 5 kg soil. $ZnSO_4·7H_2O$ and $FeSO4.7H_2O$ were sprayed on the leaves, and urea and TSP were applied to the soil just before planting. Four haricot bean seeds per pot were sown and, later, thinned to two seedlings. Grain yield, plant height, number of pods per plant and number of seeds per pod were collected. Leaves and seeds were analyzed for micronutrients using Microwave Plasma Atomic Emission Spectrometer (MPAES). Results indicated that application of NPZn and NPFe did not significantly ($p<0.05$) influence haricot bean yield compared to NP fertilizers. However, application of Zn with NP significantly increased grain yield compared to the no fertilizer treatment. The highest grain yield (16.60 g/pot) was observed at application of NPZn, while the lowest grain yield (12.80 g/pot) was observed with Fe only treatment. Plant height also followed similar trend with grain yield. Although not significant, application of Zn increased number of pods per plant compared to the no fertilizer. The most pods per plant (7.50) were observed with application of NP, while the least pods per plant (6.22) were obtained with Fe only treatment. Application of Fe and Zn either alone or combined with NP produced significantly higher tissue concentrations of the minerals than the other treatments. Therefore, fertilization of haricot beans with Fe and Zn is important in the soils of the study sites especially for quality production.

Keywords: Fe concentration, Haricot bean, NPZnFe, Zn concentration.

Introduction

Haricot bean *(Phaseolus vulgaris L.)* is one of the principal food and cash crop grown throughout the world (Tryphone and Nchimbi-Msolla, 2010) especially in developing countries (Prolla et al., 2010). It is the world's second most important commercial legume crop next to soybean 30% of its current production coming from Mexico, Central, and South America, while significant amounts are produced in Asia and Africa (CIAT, 2008). According to (Broughton et al., 2003), total production exceeds 23 million metric tons (MT) of which 7 million MT are produced in Latin America and Africa. Haricot bean provides an essential part of the daily diet and foreign earnings for Ethiopia (Girma, 2009; CARE Ethiopia, 2011). The foreign earnings are over 85 % of export earnings from pulses and about 9.5% of total export value from agriculture (Katungi et al., 2010). Haricot beans are produced in almost all the regional states of Ethiopia the major production areas being central, eastern and southern parts of the country (CSA, 2011) with average annual national production of 150 thousand tons (Ferris and Kaganzi, 2008). However, production is concentrated in Oromiya and the Southern Nation Nationalities and Peoples region (Katungi et al., 210) with annual production of 70 and 60 thousand tons (t), respectively (Ferris and Kaganzi, 2008). With this large production, the national average yield is only 1.167t ha^{-1} (CSA, 2011) attributed to various constraints among which low soil fertility could be mentioned (Ferris and Kaganzi, 2008; Girma, 2009).

Micronutrients such as iron (Fe) and zinc (Zn) are essential for optimum growth and yield of haricot beans. Singh (2004**)** reported that bean is highly sensitive to the deficiency of these minerals. In general, Fe and Zn may be needed for haricot bean where the soil is calcareous (pH greater than 7.3 because of excess free lime), coarse textured, low organic matter content, and organic soils (Ronan, 2007; Wortmann et al., 2012). The critical level of zinc in bean tissue is 15 to 20 mg kg^{-1}, while the critical level of Fe is 100 mg kg^{-1} (Ronan, 2007). (Fageria et al., 1990) indicated the sufficiency range of Fe for haricot bean tissue is from100-450 mg kg^{-1}. Improving the nutritional quality of haricot beans such as the Fe and Zn content is important in sustaining health of people relying on this crop (Ndakidemi et al., 2011). Application of around 1.5 to 2% solution of ferrous sulphate heptahydrate (FeSO4.7H2O) may be considered the best way to correct iron deficiency in haricot beans (Ferguson, 2006; Moore et al., 2012). (McKenzie, 1992) recommended that several applications of foliar sprays of 0.5% zinc sulphate heptahydrate ($ZnSO_4$. 7H2O) solution at a rate of 20 to 30 gallons per acre can supply sufficient zinc, although crop response to applied Fe and Zn may depend on the type of soil, crop and its variety, status of available nutrients, and severity of deficiency (Nayyar et al., 2001). Application of zinc caused significantly higher plant height of 53.24 cm, higher number of leaves per plant (27), maximum number of branches (12.33) (Hamsa and Puttaiah, 2012). Talukder et al. (2009) and Tryphone and Nchimbi-Msolla (2010) reported significant differences in concentrations of Fe and Zn in seeds and leaves of haricot bean.

Laboratory analysis of soils collected from Alage, Kontela, Tenkaka Umbulo, Huletegna Choroko, Taba, and Jole Andegna showed that the DTPA Zn and Fe contents of most of the soils were below 1.5 and 4.5 mg kg^{-1}, respectively, which were reported to be critical by Aref (2012), Haque et al.(2000), and Westfall and Bauder (2011). Besides, the availability of zinc and iron in these soils for production of Haricot bean was not evaluated. Therefore, this study was conducted to verify the laboratory results and evaluate the availability of zinc and iron in these soils for haricot bean production.

Materials and Methods

A greenhouse experiment was conducted to evaluate the status of Fe and Zn in soils collected from Kontela, Taba, Jole Andegna, Tenkaka Umbulo, Alage and Huletegna Choroko for haricot bean production and verify the laboratory results. The types of soils include Luvic Calcisols (Siltic) in Kontela, Haplic Calcisols (Chromic) in Alage, Haplic Calcisols (Humic) in Tenkaka Umbulo, Haplic Luvisols (Humic) in Jole Andegna, Andic Lixisols (Humic) and Andic Cambisols (Humic) in Huletegna Choroko, and Haplic Lixisols (Siltic) and Haplic Lixisols (Humic) in Taba. The soil properties of each site are indicated in Table 1.

Table 1. Physico-chemical properties of the experimental soils

Soil properties	Kontela soil	Alage soil	TU soil	JA. soil	HC soil	Taba soil
Textural class	Loam	*SCL	Loam	Clay loam	Clay loam	Clay loam
pH (H_2O)	8.1	7.51	7.39	7.4	7.70	7.47
Organic Carbon (%)	3.63	2.21	2.20	2.05	2.35	2.35
DTPA Zn (mg kg^{-1})	0.31	0.46	1.21	0.49	1.33	1.80
DTPA Fe (mg kg^{-1})	0.31	0.62	2.66	1.26	1.60	1.50
DTPA Cu (mg kg^{-1})	0.35	0.19	0.23	1.38	0.26	0.25
DTPA Mn (mg kg^{-1})	0.59	0.41	3.74	4.80	4.50	3.91
Total N (%)	0.30	0.21	0.26	0.34	0.24	0.16
Available P (mg kg^{-1})	12.20	8.21	12.25	12.13	10.00	14.30

N=nitrogen; P=phosphorus; TU=Tenkaka Umbulo; JA=Jole Andegna; HC=Huletegna Choroko; *SCL=sandy clay loam

The experiment was conducted in a randomized complete design (CRD) with seven treatments and three replications. The treatments included: (1) control, no nutrient application; (2) application of only N and P; (3) application of N, P and Zn; (4) application of N, P, and Fe; (5) application of N, P, Zn and Fe (6) application of Zn only; (7) application of Fe only. Sources of Zn, iron, N and P were $ZnSO_4.7H_2O$ (21% Zn), $FeSO_4.7H_2O$ (20% Fe), urea and TSP, respectively. TSP and urea were applied in the soil just before planting; 1% Zinc sulphate was sprayed two times after three and six weeks from sowing date (Abdel-Mawgoud et al., 2011) and 2% ferrous sulphate was sprayed 3 times in two weeks interval starting from 15 days after planting at volume of 100 L ha^{-1}. Two percent (2%) ferrous sulphate and 1% Zinc sulphate were prepared by adding 2 kg of iron sulphate and 1 kg of zinc sulphate to 100 litters of water, respectively (Incitec Pivot, 2003). Nutrients per hectare were converted in to per pot assuming that the weight of 1 ha soil in 15 cm depth is 2,000,000 kg. Five kg of soil per pot was used for the experiment and the size of the pot was 19 cm height and 19 cm diameter at top, and 16 cm diameter at bottom. The amounts of P and N were 50 mg kg^{-1} soil (0.25 g/pot) and 0.045g/pot, respectively. Four haricot bean seeds per pot were sown and later two seedlings were thinned at 10 days after sowing (Mourice and Tryphone, 2012). Haricot bean variety Nasir was used for this experiment. Grain yield, plant height, number of pods per plant and number of seeds per pod were collected. Three fully developed leaves at the top of the plant during initial flowering and seeds were collected from each treatment pot, dried in oven at 70 ºC for 24 hours, ground using a rotating sample mill. The ground plant materials were digested and analyzed for their iron, zinc, copper and manganese contents with the following procedures. Sample of 0.5 g was weighed with five digit sensitive balance in to digestion tube. Six ml of nitric acid (HNO_3) was added to each tube and placed in a digestion block at 90 ºC for 45 minutes. Then 5 ml of hydrogen peroxide (H_2O_2) was added in two splits (3 ml and 2 ml) while the samples were in digestion block and digested for another 65 minutes. Finally, 3 ml of 6 M hydrochloric acid (HCl) was added and the samples were digested until the solution has turned completely clear (for about 5 minutes). Then the tubes were taken off from the block and cooled for 20 minutes and shaken using vortex and the digests were transferred from digestion tubes in to dram vial and stored after the solution was brought to 25 ml with deionized water. The concentrations of Zn, Fe, Cu and Mn were analyzed using Microwave Plasma Atomic Emission Spectrometer (MPAES) at 213.857, 259. 940, 324.754 and 478.343 nm, respectively. Analysis of variance (ANOVA) was carried out using Proc GLM procedures in the SAS 9.3 program (SAS Institute Inc., Cary, NC USA) and Least Significant Difference (LSD) test was used for mean separation. All data from the plants grown in soils of the six locations were combined.

Results and Discussion

Application of NPZn and NPFe did not significantly ($p<0.05$) influence haricot bean yield compared to NP fertilizers (Tables 2), which is in agreement with the findings reported by Zhao et al. (2011) on dry weight of wheat. McKenzie et al. (2000) also reported that fertilization of Zn did not significantly increase seed yield of dry bean in Canada. However, application of Zn with NP significantly increased grain yield compared to the no fertilizer treatment, but did not significantly increased over the NP, and NPFe treatments. Though not significant, haricot bean fertilization with NPFe increased grain yield compared to the no fertilizer. Similarly Malakouti (2008) and Rastogi et al. (2014) reported an increase in grain yield of wheat and linseed due to application of Zn and Fe in Iran and India, respectively. Heidarian et al. (2011) also reported an increase in yield and yield components of soy bean due to fertilization of Zn and Fe. Fertilization of haricot bean only with NP did not significantly increase grain yield over the no fertilizer, and with NPZn treatments. Application of NP, NPZn, and NPFe significantly increased grain yield over NPZnFe, Zn only, and Fe only treatments. Lower grain yield was observed at application of NPZnFe than the yield obtained at application of NP, NPZn, NPFe, and with no fertilizer, which could be attributed to antagonism between Fe and Zn occurs through competition between Zn^{2+} and Fe^{2+} during uptake, and competitive inhibition between Zn and Fe during unloading in the xylem (Alloway, 2008; Kabata-Pendias, 2001). The Fe only treatment produced significantly lower grain yield than the no fertilizer indicating application of Fe alone affected the balance of NP in the soil (Poshtmasari et al., 2008). The Zn only treatment also yielded low grain though not significantly lower than the no fertilizer treatment. The highest grain yield (16.60 g/pot), which is significantly higher than the yield obtained with no fertilizer (14.73 g/pot) was observed at application of NPZn, while the lowest grain yield (12.80 g/pot) was observed with Fe only treatment.

Plant height also followed similar trend with grain yield (Table 2). Fertilization of haricot bean only with NP did not increase plant height compared to the no fertilizer treatment. Combined application of Zn and NP significantly increased plant height over the no fertilizer, NP, Zn only and Fe only treatments. A similar finding was also reported by Hamsa and Puttaiah (2012), who indicated that application of Zn significantly increased plant height. Plants grown with application of Zn and Fe with NP also were significantly taller than those grown with no fertilizer. Combined applications of Zn with NP, Fe with NP, and Zn and Fe with NP produced statistically equal height. The tallest plants (38.22 cm) were observed with NPZn, while the shortest plants (34.61cm) were obtained with Fe only treatment. Number of pods per plant was also significantly higher with NP, ZnNP, and FeNP than those with no fertilizer. On the other hand, NPZnFe, Zn only and Fe only produced statistically equal pods with the no fertilizer treatment. Though not significant, application of Zn increased number of pods per plant compared to the no fertilizer, which is in agreement with the finding reported by Nadergoli et al. (2011). This finding could be attributed to the positive effect of Zn on the formation of stamens and pollens that could increase fertility of flowers to produce more pods (Nadergoli et al., 2011). The most pods per plant (7.50) were observed with application of NP, while the least pods per plant (6.22) were obtained with Fe only treatment. Fertilization of haricot bean with NP alone or combined with Zn and/or Fe did not significantly increase seeds per pod compared to the no fertilizer treatment. Except the Fe only treatment, all treatments including the no fertilizer one produced statistically equal number of seeds per pod. Combined application of NP with Zn and/or Fe, yielded lower seeds per pod than individual application of the nutrients. The Fe only treatment produced significantly higher number seeds per pod than NP with Zn and /or Fe treatments. The most seeds per pod (5.11) were observed with Fe only treatment, whereas the least seeds per pod (4.44) were obtained with NPZnFe treatments, indicating Fe has positive effect in seed filling.

Application of Zn either alone or combined with NP and Fe produced significantly higher tissue Zn concentration than the other treatments and this is in line with the findings reported by Zhao et al. (2011) and Narwal et al. (2010) on wheat. Similar findings also were reported elsewhere by Talukder et al. (2009) and Tryphone and Nchimbi-Msolla (2010) on haricot bean in Tanzania. The highest value of leaf Zn (52.36 mg kg^{-1}) was observed with Zn only treatment, whereas the lowest value (15.75 mg kg^{-1}) was obtained with NPFe treatment. The seed Zn values obtained with applications of NPZn, NPZnFe, and Zn only were 29.94, 29.58, and 29.89 mg kg^{-1}, respectively, and are highest and statistically equal, whereas the lowest seed Zn (26.22 mg kg^{-1}) was obtained with application of Fe only. The treatments with no fertilizer, NP, NPFe, and Fe only produced statistically equal tissue Zn concentrations, which are significantly lower than the values obtained with those with Zn fertilizer. Application of Fe either individually or combined with NP and Zn yielded significantly higher tissue Fe concentrations than the rest of the treatments. All treatments with no Fe produced statistically equal tissue Fe concentrations, which were significantly lower than those with Fe fertilizer. The highest leaf and seed Fe concentrations, 293.83 and 55.79 mg kg^{-1}, respectively, were observed with NPZnFe and Fe only, respectively, whereas the lowest values of leaf and seed Fe, 162.09 and 42.76 mg kg^{-1}, respectively, were obtained with application of Zn only. Leaf Fe concentrations were by far higher in all treatments than grain Fe concentrations as reported by Nchimbi-Msolla and Tryphone (2010) suggesting that plant mineral concentrations vary between plant tissues, whereas leaf and grain Zn concentrations were relatively closer. With application of Zn fertilizer, leaf Zn was higher than seed Zn but the reverse was true in the absence of Zn fertilizer. Combined application of Zn and Fe with NP significantly increased the concentrations of Zn and Fe in leaf and seed of haricot beans. Kobraee et al. (2011) also reported that application of Zn and Fe increased concentrations of these nutrients in leaf and seed of soy bean.

Table 2. Yield, yield components and tissue concentrations of Fe and Zn as influenced by Fe and Zn fertilization

Treatment	Grain yield (g/pot)	Mean plant height (cm)	Mean no of pods per plant	Mean no of seeds per pod	Leaf Zn (mg kg^{-1})	Seed Zn (mg kg^{-1})	Leaf Fe (mg kg^{-1})	Seed Fe (mg kg^{-1})
No fertilizer	14.73bcd	34.81c	6.39c	4.83ab	20.53c	26.71b	186.15b	44.11cd
NP	15.86ab	34.58c	7.50a	4.83ab	16.97cd	27.06b	181.04b	45.99c
NPZn	16.60a	38.22a	7.39a	4.67b	44.75b	29.94a	178.12b	44.94cd
NPFe	15.31ab	36.39abc	7.17ab	4.67b	15.75d	27.06b	274.63a	52.12b
NPZnFe	13.32de	37.14ab	6.61bc	4.44b	51.40a	29.58a	293.83a	54.99a
Zn only	13.75cde	35.11bc	6.94abc	4.78ab	52.36a	29.89a	162.09b	42.76d
Fe only	12.80e	34.61c	6.22c	5.11a	18.58cd	26.22b	291.56a	55.79a
CV (%)	19.25	8.98	15.99	12.69	27.78	5.18	18.84	7.54
LSD (5%)	1.8672	2.1349	0.731	0.400	4.7546	0.9639	27.968	2.4341
P-value								
@Trt	0.0006	0.0034	0.0029	0.0663	<.0001	<.0001	<.0001	<.0001
Soil	<.0001	0.0001	<.0001	0.0123	<.0001	<.0001	<.0001	<.0001
Trt*Soil	0.1241	0.0136	0.1199	0.5226	<.0001	0.0016	0.0028	<.0001

@Trt=Treatment

Haricot bean yield, yield components and tissue Zn and Fe concentrations varied significantly across soils of the different locations (Table 3). Similar findings were reported by Nchimbi-Msolla and Tryphone (2010) in Tanzania on haricot bean. The grain yields observed in soils of Alage and Tenkaka Umbulo are significantly higher than the values obtained in soils of the other locations. The highest grain yield (18.73 g/pot) was observed in Alage soils and this value was significantly higher than the values obtained in soils of other locations, except in soils of Tenkaka Umbulo. The lowest grain yield (11.94 g/pot) was observed in Taba soils and this value is not significantly different from the values obtained in soils of Kontela, Huletegna Choroko, and Jole Andegna. The tallest plants (38.83 cm) were observed in Tenkaka soils, while the shortest (33.95 cm) were obtained in Huletegna Choroko soils. The tallest plants are significantly different from the plants grown in the rest of the locations. Number of pods per plant followed a similar trend with grain yield and plant height. The highest number of pods per plant (8.05) was observed in soils of Tenkaka Umbulo and this value is statistically equal with the value obtained in Alage soils, but higher than the values observed in soils of the rest of the locations. The lowest number of pods per plant (5.62) was obtained in Kontela soils and this value is significantly lower than the value obtained in soils of all of the rest of the locations. The number of seeds per pod observed in soils of Alage and Taba are significantly higher than the values obtained in soils of the other locations. The highest value (5.14) was produced in soils of Taba, whereas the lowest one was yielded in soils of Huletegna Choroko.

Tissue Zn and Fe concentrations also varied across locations. Significantly higher leaf Zn was produced in soils of Alage than the other locations. The highest leaf Zn (45.46 mg kg^{-1}) was observed in Alage soils, while the lowest value (23.76 mg kg^{-1}) was obtained in Kontela soils. The seed Zn concentrations observed in soils of Huletegna Choroko and Tenkaka Umbulo, 30.16 and 30.76 mg kg^{-1}, respectively, are significantly higher than the values obtained in soils of the other locations. The highest seed Zn (30.76 mg kg^{-1}) was observed in soils of Tenkaka Umbulo, while the lowest value (24.93 mg kg^{-1}) was produced in Alage soils. The lowest seed Zn is significantly lower than the values obtained in soils of all the other locations. The leaf Fe concentrations obtained in soils of Alage and Jole Andegna are significantly higher than the values observed in soils of the other locations. The highest leaf Fe (279.22 mg kg^{-1}) was observed in soils of Jole Andegna, whereas the lowest value (191.63 mg kg^{-1}) was obtained in soils of Tenkaka Umbulo. The highest seed Fe (59.50 mg kg^{-}

^{1}), which is significantly higher than the values obtained in soils of the other locations, was observed in soils of Taba, while the lowest value (41.83 mg kg^{-1}) was observed in soils of Tenkaka Umbulo.

Table 3. Yield, yield components and tissue concentrations of Fe and Zn as influenced by soil types

Soils	Grain yield (g/pot)	Mean plant height (cm)	Mean no of pods per plant	Mean no of seeds per pod	Leaf Zn (mg kg^{-1})	Seed Zn (mg kg^{-1})	Leaf Fe (mg kg^{-1})	Seed Fe (mg kg^{-1})
Alage soil	18.73a	34.86bc	7.48ab	4.90ab	45.46a	24.93e	258.13a	44.99c
*J. A. soil	13.66b	35.05bc	6.43c	4.62bc	37.10b	27.61c	279.22a	51.03b
@H.C. soil	13.54b	33.95c	6.43c	4.48c	29.98c	30.16a	217.65b	49.45b
#T. U. soil	17.08a	38.83a	8.05a	4.71bc	25.67cd	30.76a	191.63c	41.83d
Taba soil	11.94b	35.93bc	7.33b	5.14a	26.89cd	28.75b	197.28bc	59.50a
Kontela soil	12.79b	36.40b	5.62d	4.71bc	23.76d	26.18d	199.60bc	45.22c
CV (%)	19.25	8.98	15.99	12.69	27.78	5.18	18.84	7.54
LSD (5%)	1.7287	1.9766	0.6764	0.371	4.4019	0.8924	25.893	2.2535

@H. C. =Huletegna Choroko; #T. U. =Tenkaka Umbulo; *J.A. =Jole Andegna;

Fertilization of haricot bean with NP either individually or combined with Zn and /or Fe produced significantly lower tissue Cu concentrations than the no fertilizer, Zn only and Fe only treatments (Table 4). This could be attributed to the dilution effect caused by vigorous plant growth and increased yield resulted from NP application (Rajaie et al., 2009). The highest leaf and seed Cu, 4.94 and 5.70 mg kg^{-1}, respectively, were observed with application of Zn only, which is in agreement with the findings reported by Zhao et al. (2011). The no fertilizer and Zn only treatments yielded equal (5.70 mg kg^{-1}) seed Cu. Generally, application of Zn combined with NP significantly decreased tissue Cu concentration, which is in agreement with the finding reported by Rajaie et al. (2009) on lemon and Aref (2012) on maize. There was no significant difference in leaf Mn concentration among treatments, but seed Mn was significantly affected by application of NP with or without Zn or Fe. Haricot bean fertilization with NP either individually or combined with Zn or Fe, produced significantly lower seed Mn than the no fertilizer treatment, which could be attributed to the dilution effect caused by yield due NP application. Fertilization of haricot bean with Zn decreased tissue Mn concentration, which could be attributed to antagonistic relationship between Zn and Mn and this result, is in line with the finding reported by Rajaie et al. (2009) on lemon and Aref (2012) on maize. Mineral concentrations of haricot bean tissues varied significantly across locations (Table 5). Tissue Cu concentrations were significantly higher in soils of Jole Andegna than in soils of the rest of the locations. The highest leaf and seed Cu, 6.39 and 9.02 mg kg^{-1}, respectively, were observed in soils of Jole Andegna that could be attributed to the highest content of Cu in Jole Andegna soil (Table 1), whereas the lowest values, 2.39 and 2.30 mg kg^{-1}, respectively, were obtained in soils of Tenkaka Umbulo. The highest leaf and seed Mn, 244.56 and 26.57 mg kg^{-1}, respectively, were observed in soils of Kontela, while the lowest values, 125.11 and 20.87 mg kg^{-1}, respectively, were obtained in soils of Jole Andegna and Tenkaka Umbulo, respectively. This could be due to higher uptake of Mn by the plants grown in soils of Kontela than those grown in soils of the rest of the locations caused by better environmental factors for Mn uptake in Kontela.

According to Govindaraj et al. (2011), sufficiency range of Fe and Zn concentrations in critical stages of pulses, are 50-250 and 20-40 mg kg^{-1}, respectively. Hodges (2010) also reported that deficiency of Fe in most plant species occurred when the Fe content of leaves was below 10- 80 mg kg^{-1}. Munson (1998) reported that the sufficiency range of Mn in mature leaf tissue is between 20 and 300 mg kg^{-1}. Accordingly, Fe, Zn and Mn concentrations in the leaves of haricot bean with all treatments in all locations were sufficient. Leaf Cu concentration of plants grown in soils of all locations were above 2 mg kg^{-1} and sufficient, according to Kabata-Pendias and Pendias (1992), who reported that Cu tissue levels below 2 mg kg^{-1} are generally inadequate for plants.

Table 4. Effect of Fe and Zn fertilization on concentrations of Cu and Mn in haricot bean tissues

Treatment	Leaf Cu (mg kg^{-1})	Seed Cu (mg kg^{-1})	Leaf Mn (mg kg^{-1})	Seed Mn (mg kg^{-1})
No fertilizer	4.74a	5.70a	173.34a	25.17a
NP	3.62b	4.70bc	167.83a	23.50b
NPZn	3.76b	4.84b	170.37a	23.40b
NPFe	3.44b	4.33c	170.81a	23.89b
NPZnFe	3.44b	4.53bc	163.50a	23.90b
Zn only	4.94a	5.70a	168.73a	24.34ab
Fe only	4.82a	5.37a	169.26a	24.30ab
CV (%)	15.88	14.63	18.40	7.38
LSD (5%)	0.4325	0.4873	20.637	1.1784
P value				
Treatment	<.0001	<.0001	0.9835	0.0656
Soil	<.0001	<.0001	<.0001	<.0001
Treatment*Soil	<.0001	<.0001	0.1116	0.5718

Table 5. Concentrations of Cu and Mn in haricot bean tissues as influenced by soil

Soils	Leaf Cu (mg kg^{-1})	Seed Cu (mg kg^{-1})	Leaf Mn (mg kg^{-1})	Seed Mn (mg kg^{-1})
Alage soil	4.01c	4.52c	170.49b	24.69b
Jole Andegna soil	6.39a	9.02a	125.11c	21.91c
Huletegna Choroko soil	2.89d	3.70d	174.44b	24.90b
Tenkaka Umbulo soil	2.39e	2.30e	132.66c	20.87c
Taba soil	3.76c	4.85c	167.47b	25.49ab
Kontela soil	5.21b	5.76b	244.56a	26.57a
CV (%)	15.88	14.63	18.40	7.38
LSD (5%)	0.4004	0.4512	19.11	1.091

The interaction between treatment and location did not significantly affect grain yield, pods per plant, seeds per pod, and tissue Mn concentrations of haricot bean. On the other hand, plant height, concentrations of tissue Zn, Fe and Cu were significantly influenced by the interaction between treatment and location (Fig. 1, 2, 3 and 4).

Leaf Zn had weak correlations with the concentrations of all micronutrients, except seed Zn, and yield components. Leaf Fe was also weakly correlated with concentrations of micronutrients in tissues but it had significant negative and positive correlations with seed Zn (r = -0.29*) and seed Fe (r = 0.45**), respectively (Table 6). The concentrations of leaf Cu and Mn strongly but negatively correlated with number of pods per plant with r = -0.56** and -0.44**, respectively. Leaf Fe and Cu had significant but negative correlations with seed Zn with r= -0.29* and -0.42**, respectively. The concentrations of Zn, Fe, Cu and Mn in leaves had significantly and positively correlated with seed Zn, Fe, Cu and Mn, with r = 0.29*, 0.45**, 0.87*** and 0.66***, respectively, indicating that the sources and sinks of these nutrients are strongly interdependent. Similar finding was reported by Poshtmasari et al. (2008) with Fe on wheat. Leaf Cu, seed Fe and seed Cu had negative correlations with grain yield with r = -0.29*, -0.47*** and -0.36*, respectively. This finding is in agreement with earlier finding by Nchimbi-Msolla and Tryphone (2010) with Fe on common bean. Concentrations of the micronutrients in leaves and seeds, but leaf Zn, had negative correlations with grain yield suggesting that it is impossible to increase both yield and micronutrient concentrations in tissues of the same genotype (Nchimbi-Msolla and Tryphone, 2010). Sebuwufu (2013) also reported that seed Fe and Zn had negative correlations with grain yield of haricot bean. Seed Cu also negatively and significantly correlated with plant height and number of pods per plant, with r = -0.33* and -0.47**, respectively. Seed Mn positively and significantly correlated with number of pods per plant. The correlations among the concentrations of micronutrients within the leaves and seeds were weak except between seed Zn and Mn (r = -0.34*).

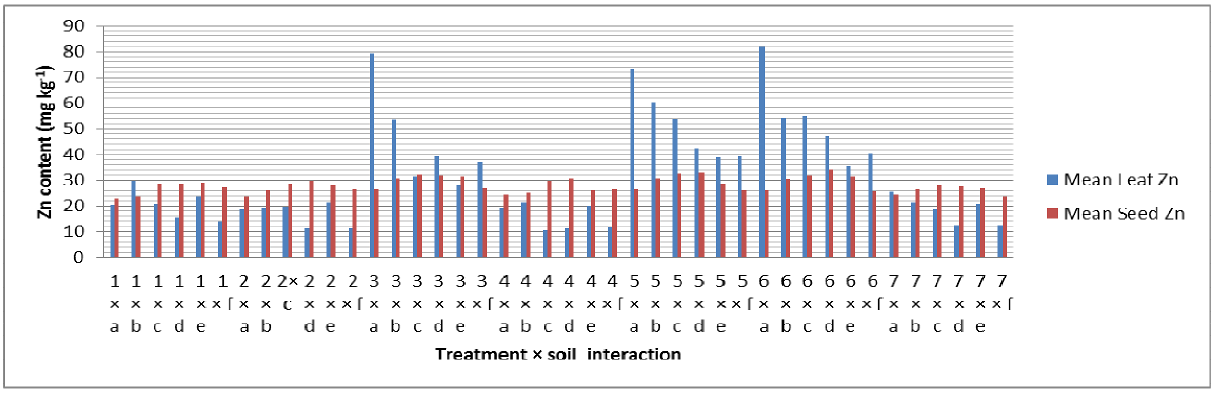

Fig. 1. Tissue Zn concentration as influence by treatment × soil interaction

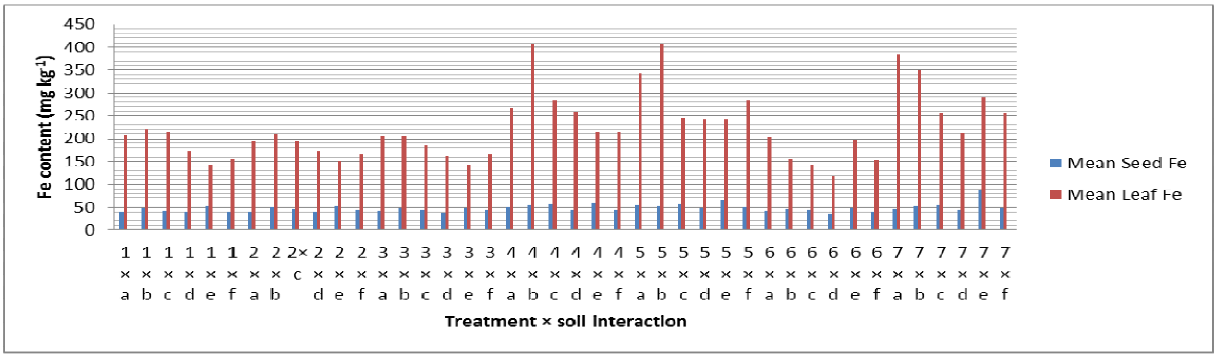

Fig.2. Tissue Fe concentration as influenced by treatment × soil interaction

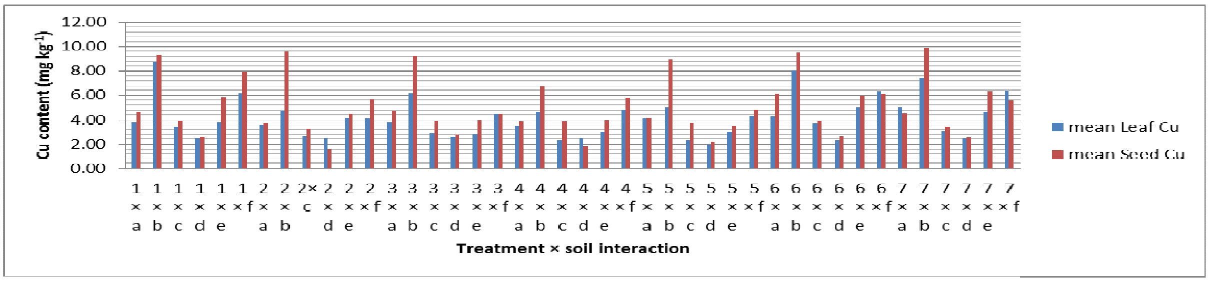

Fig. 3. Tissue Cu concentration as influenced by the interaction between treatment and location

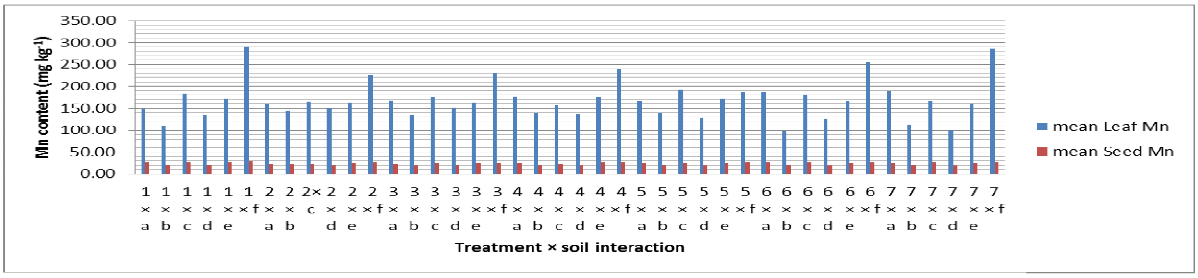

Fig. 4. Tissue Mn concentration as influenced by the interaction between treatment and location

1= no fertilizer, 2=NP, 3=NPZn, 4=NPFe, 5=NPZnFe, 6=Zn only, 7=Fe only
a=Alage, b=Jole Andegna, c=Huletegna Choroko, d=Tenkaka Umbulo, e=Taba, f=Kontela

Table 6. Correlation coefficients between concentrations of micronutrients in leaves and seeds and yield components of haricot bean

	Leaf Zn	Leaf Fe	Leaf Cu	Leaf Mn	Seed Zn	Seed Fe	Seed Cu	Seed Mn	Grain yield	Plant height	No of pods per plant
Leaf Zn	1.00	0.03	0.10	-0.12	0.29*	-0.08	0.159	-0.168	0.08	0.044	0.055
Leaf Fe		1.00	0.15	-0.15	-0.29*	0.45**	0.21	0.02	-0.05	-0.13	-0.11
Leaf Cu			1.00	0.11	-0.42**	0.07	0.87***	0.24	-0.29*	-0.26	-0.56***
Leaf Mn				1.00	-0.28	-0.08	-0.02	0.66***	-0.22	-0.03	-0.44**
Seed Zn					1.00	-0.07	-0.27	-0.34*	-0.13	0.21	0.26
Seed Fe						1.00	0.19	0.06	-0.47***	-0.14	-0.19
Seed Cu							1.00	0.07	-0.36*	-0.33*	-0.47**
Seed Mn								1.00	-0.27	-0.15	0.40**

Conclusions

Application of NPZn and NPFe did not significantly ($p<0.05$) influence haricot bean yield compared to NP fertilizers. However, application of Zn with NP significantly increased grain yield compared to the no fertilizer treatment. Though not significant, haricot bean fertilization with NPFe also increased grain yield compared to the no fertilizer. Application of Zn either alone or combined with NP and Fe produced significantly higher tissue Zn concentration than the other treatments. Fertilization of Fe either alone or combined with NP and Zn also produced significantly higher tissue Fe concentration than the other treatments. Haricot bean yield, yield components and tissue mineral concentrations varied significantly across soils of the locations. The increased grain yield due to application of NPZn (compared to both NP and no fertilizer) and NPFe (compared to no fertilizer), and the increased tissue Fe and Zn due to application of the nutrients indicate that fertilization of haricot beans with Fe and Zn is important in the soils of the study sites especially for quality production. However, further studies that include different haricot bean genotypes and levels of Fe and Zn are required for sound conclusions.

References

Abdel-Mawgoud, A.M.R; A. M. El-Bassiouny; A. Ghoname, S.D. Abou-Hussein. 2011. Foliar Application of Amino Acids and Micronutrients Enhance Performance of Green Bean Crop under Newly Reclaimed Land Conditions. Australian Journal of Basic and Applied Sciences, 5(6): 51-55, Cairo, Egypt.

Zhao, Ai-Qing, Bao Qiong-Li, Tian Xiao-Hong, Lu Xin-Chun, and William Jeff Gale. 2011.

Combined effect of iron and zinc on micronutrient levels in wheat (*Triticum aestivum* L.). J. Environ. Biol. 32:235–239.

Alloway, B.J.: Zinc in soils and crop nutrition. IZA and IFA Brussels Press, France (2008).Aref, Farshid. 2012. Manganese, iron and copper contents in leaves of maize plants (*Zea mays*L.) grown with different boron and zinc micronutrients. Afr. J. Biotechnol. 11(4):896–903.

Broughton, W. J., G. Hern´andez, M. Blair, S. Beebe, P. Gepts & J. Vanderleyden (2003). Beans (*Phaseolus* spp.)– model food legumes, *Plant and Soil* 252**:** 55–128, Kluwer Academic Publishers, the Netherlands

CARE Ethiopia. 2011. Sustainable Market Engagement: Ethiopian Farmers' Participation in Informal Seed Multiplication, Innovation Brief.

CIAT. 2008. Improved Beans for the Developing World. ANNUAL REPORT, Centro Internacional de Agricultura Tropical.

Central Statistics Authority (CSA). 2011. Agricultural Sample Survey 2010/11. Report on Area and Production of Crops (Privat3 Peasant Holdings, "Meher" Season), Vol. IV Statistical Bulletin 446, Addis Ababa: May, 2011. 1-82

Fageria, N.K., V.C. Baligar, and R.J. Wright (1990). Iron nutrition of plants: An overview on the chemistry and physiology of its deficiency and toxicity, Pesq. Agropec. Bras., Brasilia, 25(4):553-570.

Ferris S and Kaganzi E. 2008. Evaluating marketing opportunities for haricot beans inEthiopia. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers

Project Working Paper 7. ILRI (International Livestock Research Institute), Nairobi,Kenya. 68 pp.

Ferguson, Richard B. 2006. EC06-155 Nutrient Management for Agronomic Crops in Nebraska. Historical Materials from University of Nebraska- Lincoln Extension. Paper 1711

Girma Abebe. 2009. Effect of NP Fertilizer and Moisture Conservation on the Yield and Yield Components of Haricot Bean (*Phaseolus Vulgaris* L.) In the Semi-Arid Zones of the Central Rift Valley in Ethiopia. Advances in Environmental Biology, **3**: 302-307.

Govindaraj, M., P. Kannan and P. Arunachalam (2011). Implication of Micronutrients in Agriculture and

Health with Special Reference to Iron and Zinc, International Journal of Agricultural Management & Development, 1(4): 207-220

Haque, I., N. Z. Lupwayi & Tekalign Tadesse (2000): Soil micronutrient contents and relation to other soil properties in Ethiopia, Communications in Soil Science and Plant Analysis, 31:17-18, 2751-2762

Hamsa, Aparna and Puttaiah.E.T. 2012. Residual Effect of Zinc and Boron on Growth and Yield of French bean(Phaseolus vulgaris L.)-Rice (Oryza sativaL.) Cropping system. International Journal of Environmental Sciences 3, No 1, ISSN 0976 – 4402

Heidarian, A. R., H. Kord, Khodadad Mostafavi, Amir Parviz Lak, Faezeh Amini Mashhadi (2011). Investigating Fe and Zn foliar application on yield and its components of soybean (*Glycine max* (L) Merr.) at different growth stages, Academic Journals, Journal of Agricultural Biotechnology and Sustainable Development Vol. 3(9), pp. 189 -197.

Hodges SC (2010). Soil Fertility Basics. Soil Science Extension, North Carolina State Univ.

Incitec Pivot. 2003. Foliar Fertilizers Spray Guide Fact Sheet. Foliar FertilisersFS_V3.I-IPL-LM15102009.doc. Incitec Pivot Limited, Australia.

Kabata-Pendias A. and Pendias H (1992). Trace Elements in Soils and Plants, 2nd ed. Boca Raton, FL., CRC Press.

Kabata-Pendias, A. (2001). Trace elements in soils and plants, CRC Press, Boca Raton. p. 140.

Kalra, Y. P. (1998). Handbook of Reference Methods for Plant Analysis. Soil and Plant Analysis Council, Inc. CRC Press Taylor & Francis Group, Boca Raton.

Katungi, E., A. Farrow, T. Mutuoki, S. Gebeyehu, D. Karanja, F. Alemayehu, L. Sperling,

S. Beebe, J.C. Rubyogo, and R. Buruchara. 2010. Improving common bean productivity: An Analysis of socioeconomic factors in Ethiopia and Eastern Kenya. Baseline Research Report, Tropical legumes II. Centro Internacional de Agricultura Tropical–CIAT. Cali, Colombia. pp.1–126.

Kobraee, Soheil, Ghorban NoorMohamadi, Hosein HeidariSharifabad, Farokh DarvishKajori, and Babak Delkhosh. 2011. Influence of micronutrient fertilizer on soybean nutrient composition. Indian J. Sci. Technol. 4(7):763–769.

Malakouti, M. J. (2008). The Effect of Micronutrients in Ensuring Efficient Use of Macronutrients, Tübitak, Tehran – IRAN, Turk J Agric 32, 215-220

McKenzie, Ross H. 1992.Micronutrient Requirements of crops. Agri-facts. Alberta Agriculture, Food and Rural Development

McKenzie, R. H., A. B. Middleton, K.W. Seward, R. Gaudiel, C. Wildschut, and E. Bremer 2000. Fertilizer responses of dry bean in southern Alberta, Alberta, Canada.

Moore, A., A. Carey, S. Hines, and B. Brown (2012). Southern Idaho Fertilizer Guide: Beans. CIS 1189, University of Idaho.

Mourice, S.K. and G.M. Tryphone. 2012. Evaluation of Common Bean (Phaseolus vulgaris L.) Genotypes for Adaptation to Low Phosphorus, ISRN Agronomy Volume 2012, Article ID 309614, 9 pages.

Munson, Robert D. 1998. Principles of Plant Analysis. In: Y.P. Kalra editor, Handbook of Reference Methods for Plant Analysis. CRC Press, Boca Raton, Florida. pp.1–24.

Nadergoli, M. S., M. Yarnia and F. R. Khoei (2011). Effect of Zinc and Manganese and their application methods on yield and yield components of common bean *(Phaseolus vugaris L. CV. Khomein*), Middle-East Journal of Scientific Research 8 (5): 859-865.

Narwal, R. P., R. S. Malik and R. R. Dahiya (2010). Addressing variations in status of a few nutritionally important micronutrients in wheat crop, 19th World Congress of Soil Science, Soil Solutions for a Changing World, 1 – 6 August 2010, Brisbane, Australia.

Nayyar, V.K., C.L. Arora and P.K. Kataki. 2001. Management of Soil Micronutrient Deficiencies in the Rice-Wheat Cropping System, pages 87-131. *In:* Kataki, P.K. (ed). The Rice-Wheat Cropping Systems of South Asia: Efficient Production Management. Food Products Press, New York, USA.

Nchimbi-Msolla, S. and George Muhaba Tryphone (2010). The effects of the Environment on Iron and Zinc Concentrations and Performance of Common Bean (Phaseolus vulgaris L.) Genotypes, Asian Network for Scientific Information, Asian Journal of Plant Sciences 9 (8):455-462

Ndakidemi, Patrick A., Sylvia Bambara and Joachim H.J.R. Makoi. 2011. Micronutrient uptake in common bean (*Phaseolus vulgaris* L.) as affected by Rhizobium inoculation, and the supply of molybdenum and lime. Plant Omics Journal, POJ 4(1):40-52 ISSN:1836-3644 Cape Town 8000, South Africa.

Poshtmasari, H. K., Mohammad Ali Bahmanyar, Hemmatollah Pirdashti and Mohammad A. Ahmadi Shad (2008). Effects of Zn rates and application forms on protein and somemicronutrients accumulation in Common Bean (Phaseolus vulgaris L.), Asian Network for Scientific Information, Pakistan Journal of Biological Sciences 11 (7): 1042-1046

Prolla, Ivo Roberto Dorneles, Roberta Garcia Barbosa, Ana Paula Lima Veeck, Paula Rossini Augusti, Leila Picolli da Silva, Nerinéia Dalfollo Ribeiro, Tatiana Emanuelli. 2010. Cultivar, harvest year, and storage conditions affecting nutritional quality of common beans (*Phaseolus vulgaris* L.). Ciênc. Tecnol. Aliment. 30(Supl.1):96–102.

Rajaie M, Ejraie AK, Owliaie HR, Tavakoli AR (2009). Effect of zinc and boron interaction on growth and mineral composition of lemon seedlings in a calcareous soil. Int. J. Plant Prod. 3(1): 39-50

Rastogi, A., B. K. Mishra, M. Singh, R. Mishra & S. Shukla (2014) Role of micronutrients on quantitative traits and prospects of its accumulation in linseed (Linum usitatissimum L.), Archives of Agronomy and Soil Science, 60:10, 1389-1409.

Ronan, Eyal. 2007. Micro-elements in Agriculture. Practical Hydroponics and Greenhouses 95:39–48.

Sebuwufu, Gerald (2013). Physiology of genotype x soil fertility effects on yield and accumulation of iron and zinc in the common bean *(Phaseolus vulgaris L.)* seed. Graduate Theses and Dissertations. Paper 13411.

Singh, M.V. 2004. Micronutrient deficiencies in Indian soils and field usable practices for their correction. IFA International Conference on Micronutrients, 23–24 Feb. 2004, New Delhi.

Talukder, Z. I., F. Anderson, P. N. Miklas, M. W. Blair , J. Osorno ,M. Dilawari ,and K. G. Hossain. 2009. Genetic diversity and selection of genotypes to enhance Zn and Fe content in common bean. 'Mayville State University, Mayville, ND 58257, USA.

Tryphone, George Muhaba and Susan Nchimbi-Msolla. 2010. Diversity of common bean (*Phaseolus vulgaris* L.) genotypes in iron and zinc contents under screen house conditions. Afr. J. Agric. Res. 5(8):738–747.

Westfall, D.G. and T.A. Bauder. 2011. Zinc and Iron Deficiencies, Fact Sheet No. 0.545 Crop Series, Colorado State University

Wortmann, Charles S., Richard B. Ferguson, Gary W. Hergert, and Charles A. Shapiro. 2012. Use and Management of Micronutrient Fertilizers in Nebraska. University of Nebraska.