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Agronomic Approach to Increase Seed Zinc Content and Productivity of Chickpea (Cicer Arietinum L.) Varieties on Zinc Deficient Soils of Southern Ethiopia

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Abstract
Low dietary intake of Zn is the major reason for the prevalence of Zn deficiency in the majority of the population in the Southern Ethiopia. Fertilizer application is one of the agronomic approaches that enhance nutrition quality of grains in addition to its role in raising productivity. Field experiment was conducted in three locations with zinc deficient soils of Southern Ethiopia during 2012 and 2013 cropping seasons to determine zinc fertilizer rate which improve seed zinc content and productivity of chickpea varieties. A factorial combination of three chickpea varieties (Habru, Mastewal and Local) and seven zinc fertilizer rates (0, 5, 10, 15, 20, 25, and 30 kg $ZnSO_4.7H_2O$ ha^{-1}) were laid in Randomized Complete Block design within three replications. Results revealed that Habru (the improved Kabuli type) was taller (9%) than Mastewal (the improved desi type) and the local landrace. Landrace produced 7% more pods per plant than Habru. Inversely, Habru had 60% heavier seed weight than the landrace. The significant interaction effect of variety by location on grain yield, seed zinc yield and straw zinc content indicated that Mastewal was superior in grain yield at Jolle andegna and Huletegna Choroko, while landrace performed better at Taba. The landrace and Habru were superior in seed zinc yield and straw zinc content across locations, in that order. There was no significant effect of zinc fertilization on agronomic performance of chickpeas. Seed zinc content and seed zinc yield significantly varied among zinc rates. 25 kg $ZnSO_4.7H_2O$ ha^{-1} resulted in 7, 8, and 10% more seed zinc and straw zinc content and seed zinc yield over the control, respectively. Therefore, application of 25 kg $ZnSO_4.7H_2O$ with either of the varieties can be recommended for chickpeas zinc enrichment under zinc deficient soil condition of southern Ethiopia.
Keywords: seed zinc, zinc content, zinc deficient, enrichment, micronutrient, agronomic approach

INTRODUCTION

Chickpea (Cicer arietinum L.) is an important pulse crop widely used for food and fodder throughout the world. It is considered an excellent whole food and as a source of dietary proteins, carbohydrates, micronutrients, and vitamins (Jukanti et al. 2012). Chickpea has an average of 2.2–20 mg of zinc per 100 g edible portion (Ray et al. 2014).

Micronutrient deficiency affects more than 3 billion people, mostly women, infants, and children worldwide (Kay et al., 2009). In countries with a high incidence of micronutrient deficiencies, cereal-based foods represent the largest proportion of the daily diet (Cakmak, 2008). Zinc is one of the eight essential trace elements for normal healthy, growth and reproduction of plants. The element is required as a structural component of a large number of proteins, such as transcription factors and metallo-enzymes (Figueiredo et al., 2012). Ahlawat et al., (2007) reported that the main micronutrient that limits legumes productivity is zinc and its deficiency is common among chickpea-growing regions of the world.

Micronutrient deficiency remains a significant public health concern; especially deficiencies in iron, vitamin A, folic acid, iodine and zinc are commonly observed affecting the physical and mental functioning and growth, brain development in pregnancy, visual impairment, increased susceptibility to disease and increase mortality risk (UNICEF, 2014). In Ethiopia, malnutrition is common on 52% of the rural population; particularly children and women do not get the minimum consumption requirements for calories (CIFSRF, 2012). The problem is acute in southern Ethiopia where the livelihoods and diets are heavily dependent on cereals and root crops, which are inherently low in micronutrients and high in carbohydrates.

Several studies have been conducted throughout the world regarding micronutrient fertilizer rate determination under micronutrient deficient condition (Loneragan and Webb, 1993; Khan et al., 2004; Valenciano et al., 2010). The magnitude of yield losses due to nutrient deficiency also varies among the nutrients (Ali et al., 2008). Chickpea is generally considered sensitive to Zn deficiency, although there are differences in sensitivity among varieties (Ahlawat et al., 2007).

Fertilization is one of the agronomic management strategies to enhance nutrition quality of chickpea grains in addition to its role in raising productivity (Pathak et al., 2012). Application of Zn had a significantly positive effect on seed Zn concentrations and grain yield, especially under Zn deficient conditions (Wei et al., 2007). Grain yield increased with increase in the application of zinc from zero to 10 mg kg^{-1} soil in lentil, Fenugreek, gram and peas (125%, 63%, 37% and 22%, respectively) over the control (Wei et al., 2007; Gupta et al. 1999). Similarly, Shelge et al. (2000) noticed that increased seed yield (2203 kg ha^{-1}) due to application of 5 kg $ZnSO_4$ ha^{-1} and borax at 0.5 kg ha^{-1} (1973 kg ha^{-1}) in soybean.

Soil application of Cu, Zn, and Mo is more efficient than Mn and Fe fertilization, on most soils, but all transition metal nutrients are not readily translocated within plants on deficient soil (Yilmaz et al. 1998). However, such information for Ethiopian chickpea materials under diverse soil and agro-climatic conditions is limited. Based on these facts, this study was initiated with the objectives of: 1) to determine optimum zinc fertilizer rates for growth and grain yield of chickpea varieties; and 2) to evaluate the seed and straw zinc concentration and seed zinc yield (up take) response of chickpeas varieties to zinc fertilization application rates.

MATERIALS AND METHODS

Description of the Study Areas

The experiment was conducted at three locations, Jolle andegna, Taba and Huletegna choroko during 2012 and 2013 cropping seasons (Table 1). The monthly meteorological data of the test locations during the growing seasons of 2012 and 2013 is presented in Table 2. Jolle andegna, one of the locations where the first season planting was made in late September, encountered moisture stress during flowering and pod filling stage of the crop. As indicated in Table 2, in this location, the rainfall was drastically declining starting from October and no rain in November while the mean temperature was increasing during the pod filling stage of the crop.

Table 1 Description of the experiment sites

Location	Altitude (*masl)	Annual RF (mm)	Mean annual Temperature (°C)	Soil texture	Zone
Jolle Andegna	1923	922	18.4	Silty clay loam	Gurage
Taba	1915	989	18.7	Silty loam	Wolayita
Huletegna Choroko	1807	774	20.6	Clay loam	Huletegna Choroko

* masl = meter above sea level, mm = millimetre, °C = degree siliceous; Source: (NMA, 2013) and Collage soil laboratory.

Table 2. Monthly meteorological data of the test locations during the 2012 and 2013 growing seasons

Location	Months	RF(mm)		Temperature (°C)					
				Maximum		Minimum		Mean	
		2012	2013	2012	2013	2012	2013	2012	2013
Huletegna Choroko	August	89.5	178.1	25.3	24.9	14.4	17.6	19.9	21.3
	September	100.7	138.8	27.1	28.2	14.1	17.4	20.6	22.8
	October	10.0	118.9	30.3	29.0	11.8	16.7	21.1	22.9
	November	9.0	60.3	31.7	30.2	12.0	11.8	21.9	21.0
	December	2.6	0.2	31.0	30.0	12.5	12.3	21.8	21.2
Taba	August	169.7	223.0	21.5	21.5	13.5	13.4	17.5	17.5
	September	135.3	210.0	22.7	23.2	13.6	13.6	18.2	18.4
	October	13.0	150.0	26.2	24.2	13.5	13.6	19.9	18.9
	November	32.6	39.0	26.9	25.9	13.2	13.1	20.1	19.5
	December	16.8	16.0	27.3	26.5	12.8	12.6	20.1	19.6
Jolle Andegna	August	143.9	164.7	22.6	23.0	10.2	11.0	16.4	17.0
	September	88.0	48.1	24.1	28.4	9.9	11.2	17.0	19.8
	October	15.8	50.1	27.0	26.8	9.8	10.0	18.4	18.4
	November	0.0	25.0	27.0	26.8	9.1	9.5	18.1	18.2
	December	3.5	11.0	26.5	26.4	8.5	8.2	17.5	17.3

Source: National Meteorological Agency, Southern Zone, Awassa branch (NMA, 2014)

Experimental treatments and design

The study was carried out using three chickpea varieties (Mastewal (Desi type), Habru (Kabuli type) and one landrace) and seven zinc fertilizer rates (0, 5, 10, 15, 20, 25, and 30 kg $ZnSO_4.7H_2O$ ha^{-1}) on three selected zinc deficient soils. The design of the experiment was laid out in factorial combination using Randomized Complete Block Design (RCBD) with three replications. A 3.2 m by 3.5 m long (11.2 m^2) gross plot size and 2.4 m by 3.5 m long (8.4 m^2) net plot size having a spacing of 40 cm and 10 cm between rows and between plants was used, respectively. Zinc fertilizer ($ZnSO_4.7H_2O$) drilled in rows of experimental plots and mixed with soil using sticks before sowing. To avoid residual effects, the experiment in 2013 was conducted on a separate site in the same location. Chickpea seeds were tested for their viability for germination and were viable with germination of more than 85%. Two chickpea seeds placed per shallow hill of about 5cm at 10 cm apart and covered manually with fine soil. Fifteen days after emergence, the extra plants thinned to maintain optimum population of 35 plants row^{-1}.

Data collection

Plant heights, number of pod bearing branches, number of pods plant^{-1} were recorded from 10 randomly selected plants from the middle six rows in each plot. Seeds weight was determined by counting 250 seeds and weighing on a digital balance and converted to 1000 seeds weight. Above ground biomass and grain yield were measured from harvest made on the middle six rows (2.4m*3.5m=8.4 m^2) plot at ripening. The grain per plot was adjusted to storage moisture content based on the value of actual grain moisture read by using digital grain moisture tester (HOH-EXPRESS HE 50). Grain zinc yield ha^{-1} was calculated based on grain zinc content (mg ka^{-1}) and grain yield (ton ha^{-1}).

Soil samples

Fifteen soil samples from a depth of 0-30 cm were randomly collected before sowing across the trial field with auger and mixed together as a composite sample to assess the physical and chemical properties including soil zinc concentration. Soil samples were air-dried, cleaned off any stones and plant residues, grounded in stainless steel soil grinder and allowed to pass a 2 mm sieve for analysis. The sieved soil samples were collected, labeled for the required analysis. The soil Zn concentration was extracted with DTPA and determined by Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). Available P was determined using Olsen strategy by extracting the soil sample with 0.5M sodium bicarbonate at pH 8.5 (Olsen and Sommers, 1982). Soil organic carbon was determined following the Walkley (1947) procedure. Details of the soil properties for the experimental fields are shown in Table 3.

Plant samples

Chickpeas seed and straw zinc concentration analysis was conducted at the University of Saskatchewan, SK, Canada. Subsamples of seeds and straws for determination of zinc concentration were taken randomly from the entire harvested lot of each of three replicated randomized field plots at each location. Each replicated seed and straw samples were prepared by a standard HNO_3–H_2O_2 digestion method (Thavarajah et al., 2009), using wet digestion with nitric acid followed by atomic absorption spectrometry. Zinc concentrations measured by this method were validated using NIST standard reference material 1573a. Red berry lentil seeds and organic wheat (Triticum aestivum L.) were used as laboratory reference materials and measured periodically to ensure consistency in the method. Concentration was measured using flame atomic absorption spectrometry (AJ ANOVA 300, Lab Synergy).

Statistical Analysis

Phonological, yield components, yield and zinc concentration data were collected from harvestable lots of each plot and subjected to analysis of variance using the GLM procedure of SAS computer package (SAS, 2008). Effects were considered significant in all statistical calculations if the P-values were < 0.05. Means were separated using Fisher's Least Significant Difference (LSD) test. Seed zinc yield (zinc uptake) was calculated by multiplying grain yield (tone ha^{-1}) with grain zinc concentration (mg kg^{-1}).

RESULTS AND DISCUSSION

Results of soil physico-chemical property analysis indicated that the entire test locations have a pH values of above 6, and ***Diethylene Triamine Pentaacetic Acid*** (DTPA) extracted zinc concentration ranging from 0.13ppm at Taba to 0.98 ppm at Huletegna Choroko representing the locations are zinc deficient. There was marked organic carbon variation ranging from 0.99 at Taba in 2012 to 1.78 at Huletegna Choroko (Table 3).

Table.3. Soil properties of the experimental field

Location	Year	pH (1:2.5)	EC	Zn (mg kg^{-1})	%OC	Total N%	Available P (mg kg^{-1})
Jolle Andegna	2012	6.77	0.20	0.17	1.71	0.57	27.1
	2013	6.82	0.22	0.19	1.70	0.65	30.2
Taba	2012	6.36	0.05	0.13	0.99	0.71	36.5
	2013	6.40	0.07	0.16	1.10	0.83	35.6
Huletegna Choroko	2012	6.73	0.08	0.98	1.78	0.44	37.6
	2013	6.93	0.09	0.94	1.73	0.46	38.0

Note: EC==electro conductivity, %OC= percent organic carbon, L= loam, Soils have low Zn availability when there is less than to 1.1 mg Zn kg–1 soil (DTPA extraction) Ankerman and Large (1974), The critical Zn concentrations in soils vary from 0.48 mg kg–1 to 2.5 mg kg–1 depending on soil type (Ahlawat et al., (2007).

As previously presented in Table 2, total amount of rainfall in 2013 and the long-term average was greater by 13 and 35%, 42 and 18%, 57 and 40% at Jolle Andegna, Taba and Huletegna Choroko, than that of 2012, in that order. The distribution of rainfall in 2012 crop season was uneven with most of the days without rain and some days with less than 5 mm. Relatively higher and evenly distributed rainfall in 2013 means longer crop growth duration and more biomass accumulation, subsequently, more grain yield as compared to 2012.

Growth of chickpea

There was significant ($P<0.01$) number of pod bearing branches variation observed across locations (Table 4). Jolle andegna and Taba produced 73 and 82% more pod bearing branches than Huletegna Choroko, respectively (Table 5). The variation of plant height to variety was significant indicating that Habru was taller than both Mastewal and land race. However, neither number of pod bearing branches nor above ground biomass differed significantly to varieties. Similarly, Zinc fertilization had no significant effect on plant height, number of pod-bearing branches and aboveground biomass. In general, zinc fertilization did not influence agronomic performance of the crop (Table 4 and 5).

Table 4. ANOVA mean square for growth of chickpea to zinc fertilizer rates

Sources of variation	df	Plant height	Pod BB	Aboveground biomass
L(Location)	2	494	2900***	70.40
V(variety)	2	907*	365	26.25
L*V	4	140	31	22.33
ZR(zinc rate)	6	12	28	3.79
L*ZR	12	11	10	2.22
V*ZR	12	22	18	1.06
L*V*ZR	24	21	15	1.77
CV%		9.05	20.44	14.54

df = degree of freedom, pod BB=number of pod bearing branches.

Table 5. Effects of location, variety and zinc rate on plant height, pod-bearing branches, and above ground biomass of chickpeas.

Treatments		Plant height (cm)	Pod bearing branches	Above ground biomass(t ha^{-1})
Location	Jolle Andegna	59.7	19a	5.84
	Taba	53.7	20a	6.93
	Huletegna Choroko	51.8	11b	5.50
	$LSD_{5\%}$	NS	0.86	NS
Variety	Habru	54.8a	15	6.18
	Mastewal	50.1b	18	6.49
	Local	50.3b	18	5.60
	$LSD_{5\%}$	1.16	NS	NS
Zn rate (kg $ZnSO_4.7H_2O$ ha^{-1})	0	51.6	17	5.91
	5	52.2	17	6.49
	10	51.9	16	6.27
	15	52.5	17	6.33
	20	51.2	18	5.92
	25	51.6	16	5.84
	30	51.2	17	5.86
	$LSD_{5\%}$	NS	NS	NS

Note: Means with the same letter are not significantly different, NS=non significant

Yield components, yield, and harvest index

There was significant number of pods per plant, grain yield and harvest index variation observed across locations but thousand seed weight was not significant (Table 6). The effect of varieties on number of pods $plant^{-1}$ and thousand seed weight was statistically significant ($P<0.05$ and $P<0.01$), respectively (Table 6). Landrace produced 7% highest number of pods per plant than Habru. Inversely, Habru had heavier thousand seed weight than the landrace. The seed weight variation between the two varieties (Habru and Landrace) was more than 154 %. The most probable reason for varietal difference was the physiological mechanism that a crop species can tolerate the existing environment. It has been well documented that certain plant species, as well as genotypes within certain species, exhibit a significant genetic-based variation in their tolerance to Zn deficiency (Kochian and Hacisalihoglu, 2003). Though the effect of variety on grain yield was not significant, Mastewal produced 23 and 15% more grain yield than Habru and landrace, in that order (Table 7). There was no significant harvest Index (HI) difference observed among varieties

Table 6. ANOVA for yield components, grain yield and harvest index response of chickpea varieties to zinc fertilizer rates

Sources of variation	df	pods $plant^{-1}$	Thousand seed weight	Grain yield	Harvest index
L(Location)	2	23108	6321	10.26	0.704
V(variety)	2	948*	1037400***	10.23	0.143
L*V	4	76	1786	4.86*	0.013
ZR(zinc rate)	6	13	259	0.29	0.002
L*ZR	12	16	185	0.28	0.001
V*ZR	12	18	399	0.18	0.004
L*V*ZR	24	19	364	0.33	0.003
CV%		7.13	7.94	6.71	13.81

df=degree of freedom, podBB=number of pod bearing branches, grain zn=grain zinc concentration, *=P<0.05, ***=P<0.01

Similar to growth response, Zn application had no significant effect on yield components, yield and HI (Table 6). In a study conducted by Khan et al., (1998) on 13 chickpea varieties, it was reported that, the Zn application created different effects on the varieties regarding the dry matter production of the aerial parts; although, dry matter production maintained an increase in some varieties, it did not cause a significant change in certain others at the end of the growing period. Similarly, Akay (2011) reported that application of Zn did not provide a significant increase in yield of chickpea varieties. Correspondingly, application of Zn increase yield with rate but the increase was not statistically significant (Hatice et al., 2007). Singh et al. (1987) also reported that there were no significant yield responses to zinc fertilization in several dry land annual crops. Several authors reported that crop response to Zn is certainly depends on crop type. For instance, increased yield have been observed in rice (Shivay et al., 2008), corn (Singh et al., 1979), and wheat (Cakmak et al., 1999) grown on soils ranging in pH 7.2-8.8 and initial DTPA-extractable soil levels of 0.01-0.78 mg Zn kg^{-1} when soil applied $ZnSO_4$ had been broadcast and incorporated ranging from 5 to 23 kg Zn ha^{-1}.

Table 7. Effect of location, variety and Zn fertilizer rates on pods $plant^{-1}$, thousand seed weight, grain yield, and harvest index

Treatments		Pods $plant^{-1}$	Thousand seed weight(g)	Grain yield (t ha^{-1})	Harvest Index
Location	Jolle Andegna	50	220	2.89	0.53
	Taba	73	206	2.38	0.39
	Huletegna Choroko	73	212	2.42	0.41
	$LSD_{5\%}$	NS	NS	NS	NS
Variety					
	Habru	63c	297a	2.34	0.40
	Mastewal	65b	224b	2.88	0.47
	Local	68a	117c	2.50	0.45
	$LSD_{5\%}$	1.16	5.02	NS	NS
Zn rate (kg $ZnSO_4.7H_2O$ ha^{-1})	0	65	212	2.52	0.44
	5	66	212	2.67	0.44
	10	65	216	2.60	0.44
	15	66	209	2.63	0.43
	20	65	212	2.46	0.45
	25	66	214	2.54	0.45
	30	66	214	2.53	0.44
	$LSD_{5\%}$	NS	NS	NS	NS

Note: Means with the same letter are not significantly different, NS=non-significant

The interaction effect of location and variety to grain yield was significant. Mastewal produced significantly superior grain yield at Jolle Andegna and Huletegna Choroko. This variety had 40 and 30%; 41 and 24 % grain yield advantage over the varieties Habru and land race at the specified locations, respectively (Fig.1).

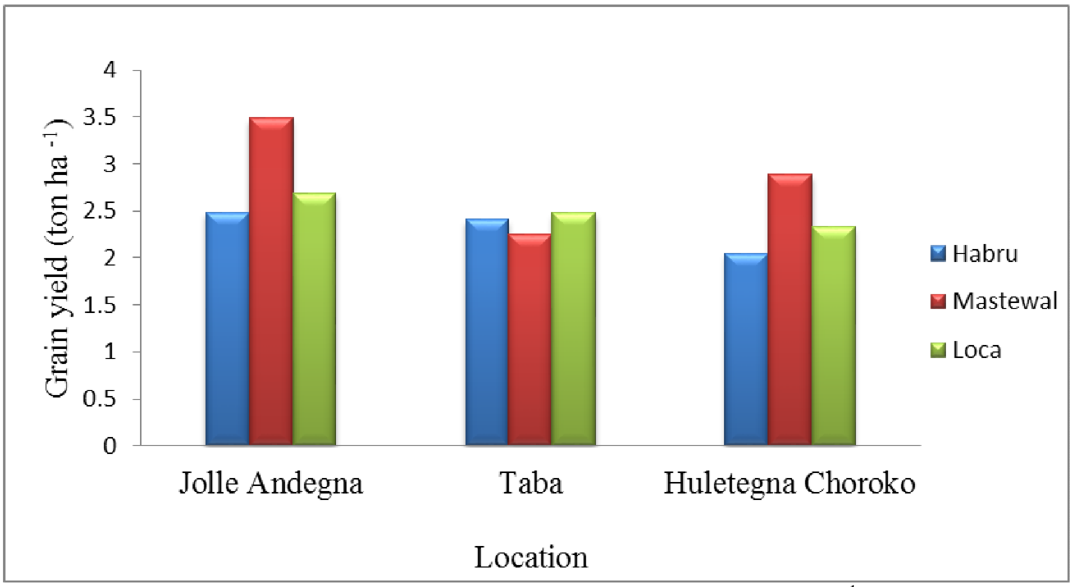

Figure 1. Effect of location and variety interaction on grain yield (ton ha $^{-1}$) of chickpeas

Grain and straw Zn content, and grain zinc yield.

There was highly significant ($P<0.01$) grain zinc content difference observed among locations (Table 8). Huletegna Choroko produced 32% more grain zinc content than both Taba and Jolle Andegna (Table 9). Similarly, the effect of zinc fertilizer application on Zn content in grain was significant (Table 8). Forty mg Zn kg^{-1} grain obtained from the application of 25 kg $ZnSO_4.7H_2O$ ha^{-1} was the highest followed by thirty-nine mg Zn kg^{-1} grain of 30 kg $ZnSO_4.7H_2O$ ha^{-1}. Both rates had 7 and 6% more grain zinc content over the control (no fertilized plots), respectively. Grain Zn yield also showed similar trend. Application of 25 kg $ZnSO_4.7H_2O$ ha^{-1} resulted in 9% more grain Zn yield over the control (Table 9). On the other hand, Zn application had no significant effect on straw Zn content of chickpeas. The effect of variety on straw zinc content was significant. Habru produced 26 and 13% more straw Zn than Mastewal and land race, respectively (Table 9).

Table 8 ANOVA for grain and straw Zn content and grain Zn yield of chickpea varieties to Zn fertilizer rates

Source of variation	df	Grain zinc	Straw Zn	Zn yield
L(Location)	2	9065***	3457	44235
V(variety)	2	48	1297*	16355
L*V	4	8	232*	6498***
ZR(zinc rate)	6	320***	51	1959*
L*ZR	12	36	29	811
V*ZR	12	9	30	470
L*V*ZR	24	5	20	490
CV%		9.25	7.85	11.78

df = degree of freedom, pod BB=pod bearing branches, and grain Zn=grain zinc concentration.

Table 9. Effect of location, variety and Zn rate on grain and straw Zn content (mg kg-1) and zinc yield (g ha-1) of chickpeas

Treatments		Straw Zn (mg kg-1)	Grain Zn (mg kg-1)	Zn yield (g ha-1)
Location	Jolle Andegna	22.14	31.75b	90.8
	Taba	16.32	31.64b	74.7
	Huletegna Choroko	26.77	46.39a	112.1
	$LSD_{5\%}$	NS	0.84	NS
Variety	Habru	24.96a	36.11	81.6
	Mastewal	18.55c	36.38	104.3
	Local	21.72b	37.29	91.6
	$LSD_{5\%}$	0.42	NS	NS
Zn rate (kg $ZnSO_4.7H_2O$ ha^{-1})	0	20.63	37.05b	91.0b
	5	20.48	37.54b	98.3a
	10	23.24	34.20d	87.7bc
	15	22.15	33.11d	86.2c
	20	21.82	35.52c	86.3c
	25	21.57	39.55a	99.7a
	30	22.31	39.18a	98.0a
	$LSD_{5\%}$	NS	1.28	4.10

Note: Means with the same letter are not significantly different, NS=not-significant

The effect of location and variety interaction on grain zinc yield was significant (P=0.01). The mean zinc yield obtained from Landrace and variety Habru at Taba found to be superior, whereas, the variety Mastewal had comparable zinc yield across locations except at Huletegna Choroko where slight increase observed when compared to other locations (Fig. 2).

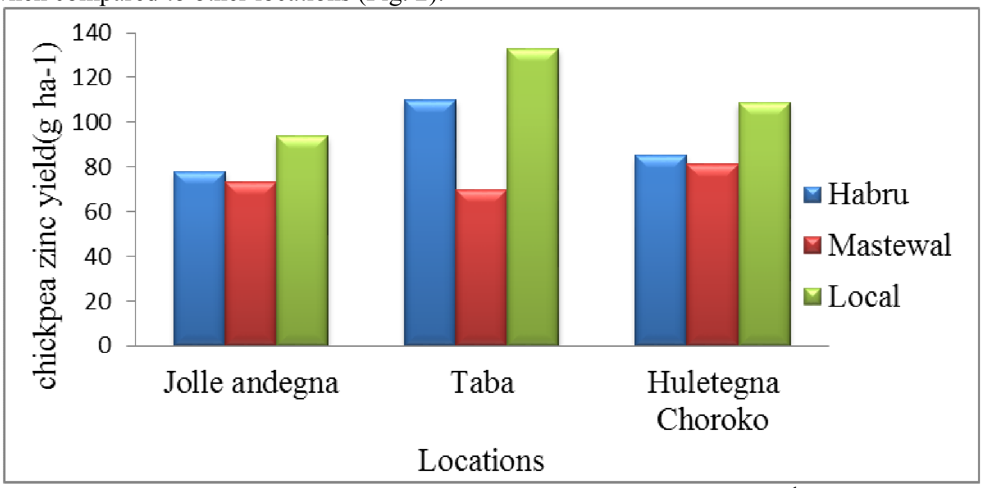

Figure.2. Effect of variety and location interaction on zinc yield (g ha^{-1}) of chickpea

The interaction effect of variety by location on straw zinc concentration was significant with Habru had superior across location followed by land race except at Huletegna Choroko where the variety Mastewal found to be better than Landrace (Fig. 3).

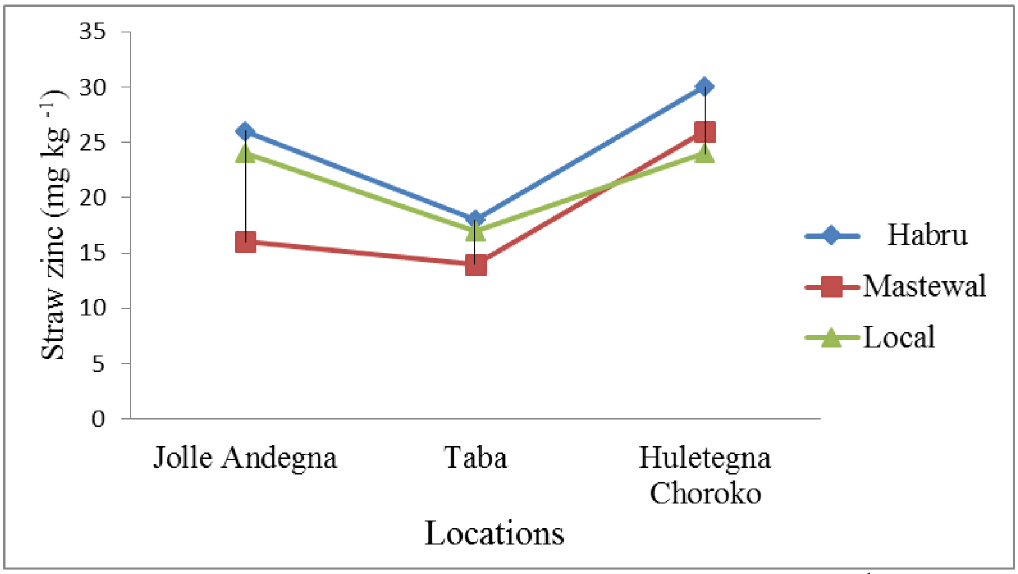

Figure 3. Effect of location and variety interaction on straw zinc Content (mg kg $^{-1}$) of chickpeas

Association of tested parameters

The result of correlation analysis (Table 10) revealed significant (P=0.0001) and positive relationship of number of pods per plant with grain yield, zinc content in the seed and zinc yield having r values of 0.44, 0.21, and 0.50, respectively. However, it had significant but inverse correlation with thousand seed weight and straw zinc content (r=-0.12 and -0.51), in that order. The correlation between zinc content in seed and straw with grain yield was significant but negative (r= -0.15 and -0.48), correspondingly. The negative and significant correlation of grain yield with seed Zn concentration of present study was in full agreement with previous work. For instance, Diapari et al., (2014) also reported that there was negative correlation between grain Zn concentration and grain yield whereas their correlation with 100 seed weight was not significant. Grain yield with seed zinc yield had strong, positive and highly significant (P<0.0001) correlation (r=0.84) which indicated that the increase in grain yield may predict the higher seed zinc yield. Similar result also reported by Omar and Singh (1997).There was no significant correlation between seed weight and zinc content in the seed. Moreover, the correlation between zinc content in the seed and straw was positive and significant (r=0.41).

Table 10. Pearson Correlation Coefficients

	ppp	yton	tsw	Sdzn	znyld	St zn
ppp	-					
yton	0.44***	-				
tsw	-0.12***	0.10*	-			
sdZn	0.21***	-0.15***	-0.06	-		
znyld	0.50***	0.84***	0.049	0.38***	-	
stZn	-0.51***	-0.48***	0.16***	0.41***	-0.24***	-

Note: ppp=pods per plant, yton=yield in tones ha^{-1}, tsw=thousand seed weight, sdzn=seed zinc content, znyld= seed zinc yield g ha^{-1}, stzn= straw zinc content.

CONCLUSION

Significant grain Zn concentration and grain zinc yield improvement to Zn fertilizer application inveterate that there is a possibility to chickpea bio-fortification through agronomic approach. The highest grain Zn concentration and grain zinc yield obtained from the application of 25 kg $ZnSO_4.7H_2O$ (about 5 kg Zn ha^{-1}) with either of the varieties was attractive option in solving Zn deficiency-related health problems for resource poor farmers who cannot afford fortified foods for their nutrition security and thus, recommended for chickpeas Zn enrichment under Zn deficient soil conditions of southern Ethiopia.

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