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Orange (*cv Valencia*) Response to Foliar Application of Micronutrients at Merti-Abadiska in the Central Rift Valley of Ethiopia

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Effect of micronutrients including Chelated Iron 13.2% (Fe) Zinc 14% (Zn), Copper 14% (Cu), Manganese 13% (Mn), and Blended Zinc 4.0% (Zn) & Boron 2% (B) as foliar spray on fruit yield and quality of orange, cv. Valencia at Upper Awash Agro Industry Enterprise (Merti-Abadiska farm), Ethiopia were studied during 2011 to 2013. The experiment was laid out in randomized complete block design and replicated three times. The product solution was prepared as per factory recommendations (1.12 kg of micronutrients dissolved in 640 L ha^{-1}) and was applied as foliar spray at two different growth stages (before flower initiation and after nine months of the first spray). The result showed that foliar application of Fe, Zn and Cu significantly affected micronutrient concentration of the leaves ($p< 0.05$). As a result, the fruit yield and fruit qualities were improved: fruit yield 25.0 to50. 6%, TSS from 3.7 to 14.8%, and sugar content by 2.5 to 5.0% when compared to the control. Therefore, it is concluded that the foliar application of micronutrients at the rate of 1.12 in 640 L of water per hectare at least twice per annum improved the quality parameters and increase the fruit production of citrus orchard in the Central Rift Valley of Ethiopia.

Key words: Micronutrient, foliar spray, Merti-AbadisKa, Orange

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INTRODUCTION

Balanced uses of nutrients both for macro- and micro-nutrients have been shown important to meet higher agricultural production (Patel et al., 2009). Contrary to this, the fertilizer use in Ethiopia has focused mainly on the use and application of nitrogen and phosphorous fertilizers in the form of urea and diammonium phosphate (DAP) for almost all cultivated crops in the last three to four decades. It has been reported that, with the favorable developments in the use of nitrogen and phosphorus fertilizers to increase crop production, the amount of micronutrients annually removed with crop harvest increases by about two to six times than are applied to it (Katyal et al., 1983). This holds true in countries like Ethiopia where there is no micronutrient application in the form of inorganic fertilizer or organic chelate. Some reports indicated that elements including micro-nutrients particularly Cu, Mn, B, Mo and Zn are becoming limited and deficiency symptoms are being observed on major crops in different parts of the country (Asgelil *et al*., 2007) and the Nura-Era citrus farm in the central Rift Valley of Ethiopia (Dejene, 2009).

Most of micronutrients are associated with the enzymatic system of plants. Zinc which is required to make auxin, the plant hormone responsible for cell elongation and growth (Beede et al., 2005), is essential metal for normal plant growth and development (Broadley et al., 2007). Like zinc, copper is also a component of many enzymes in the plant and plays a role in energy metabolism and plant reproductive growth (Beede et al., 2005). Fe and Cu play key roles in several enzyme-systems that contributes vital function in overall plant-metabolism (Romheld et al., 1991) while Mn is important activator of numerous enzymes in the cell (Wiedenhoeft, 2006). Boron (B) on the other hand plays important role in growth and productivity of citrus. It initiates pollen grain germination, pollen tube elongation, consequently fruit set percentage and finally the yield (Abd-Allah, 2006). Thus, micronutrient deficiency and toxicity can reduce plant yield (Tisdale et al., 2003).

The availability of micronutrient to plant growth is particularly sensitive to soil environmental factors like organic matter, soil pH, lime content and soil texture (Nazif *et al.,* 2006). Micronutrient application to alkaline soils is indicated usually adsorbed or fixed on the surface and does not move readily to the root zone (Embleton *et al*., 1973). Zinc solubility in soils for instance is reported to decrease by up to 100 fold per unit increase in soil pH and adsorption of this element by calcium carbonate ($CaCO_3$) is attributed to account for high Zn deficiency incidence on calcareous soils. The carbonate found in such soils forms an insoluble complex with Zn added as zinc sulfate (Rasouli-Sadeghiani *et al.,* 2002). Hence, Zn deficiency is frequently observed in alkaline soils, and can be aggravated by high level of phosphate or nitrogen fertilization (Langthasa et al., 1995; Boaretto *et al.,* 2002). Iron (Fe) deficiency induced leaf chlorosis is also a major nutritional disorder in calcareous soils (Alvarez-Fernandez *et al*., 2006) and visible symptom in orange trees (Pestana *et al*., 2001). Iron deficiency in fruit trees causes chlorosis, decreases in vegetative growth, reduced fruit yield and quality. Iron deficiency chlorosis in fruit trees is mainly resulted from impaired acquisition and use of the metal by plants, rather than from a low level of Fe in soils.

Citrus, being deep rooted crop, micronutrients application to soil may be of little value. The alternative way is foliar spray which has shown advantages over soil application because of high effectiveness, rapid plant response, convenience and elimination of toxicity symptoms brought about by excessive soil accumulation of such nutrients (Obreza *et al*., 2010). Curing micronutrient deficiencies through foliar application is a common practice in getting profitable yield and good quality fruit (Leyden, 1983). Keeping in view, the unfavorable physico-chemical conditions (high pH and calcareous nature) of the soils of the study area (Dejene, 2009), foliar spray of micronutrients in proper amount is preferred to improve citrus productivity

Citrus is one of the important tropical fruit crop of the world and also to Ethiopia. It has a great nutritional role on our daily diet, being a rich source of vitamin C. Upper Awash Agro Industry Enterprise (UAAIE) is the biggest citrus farm in the country on relatively high pH soils. However there are reports and symptoms of Zn and Fe deficiency for citrus farms of the Enterprise (Asgelil et al., 2007; Dejene 2009) study conducted on the effect of micronutrients on orange yield through foliar application in Ethiopia is scanty. These, therefore necessitate determination of response of orange to foliar application of micronutrients in the study area. Thus, the specific objective of the present study was:

- to determine the response of orange to foliar applications of micronutrient (Zn, Cu, Mn, Fe and/or B)

MATERIAL AND METHOD

Area description

Abadiska-Merti Citrus farm (about 5 ha) is among citrus farm of the country operating under Upper Awash Agro Industry Enterprise (UAAIE). The UAAIE is state owned, under which over 1000 ha of citrus production farm of the country is located. The farm is located in East Showa zone at some 200 kms from Addis Ababa near Merti processing plant at the latitude of 8^0 34' 15.4''N and 39^0 40' 28.8''E at the elevation of 1200 masl. Annual rainfall is only 611 mm and hence irrigation water mainly from Awash River is used for the farm. The maximum and minimum temperature of the area is 34.2 ^{0}C and 14 ^{0}C respectively.

Site selection and treatment arrangement

This experiment was conducted on 5-year old trees of orange, *cv. Valencia* at Abadiska-Merti farm. Six treatments with three replications were arranged in a randomized complete block design. Similar sized five trees per plot and a total of ninety trees for the entire experiment were selected, growing under similar conditions of soil fertility and irrigation and each tree was tagged.

In addition to the full basal dose of 146 kg N ha^{-1} and 138 kg P_2O_5 ha^{-1} from .urea and DAP, the enterprise agricultural practices, 51 kg K_2O ha^{-1} (470g potassium sulfate $tree^{-1}$) was applied under the canopy of each tagged tree on the irrigation rings of the tree and trees were then irrigated. Five micronutrient products (iron chelate, zinc chelate, copper chelate, manganese chelate and zinc-boron blend) at a single rate according to the product recommendations were applied at the following two stages:

i. before flower initiation and
ii. after 9 months of the 1st spray.

Cu chelate (14% Cu), Zn chelate (14% Zn), Mn chelate (13% Mn), Fe chelate (13.2% Fe) and Zn-B chelate (5% Zn and 2% B), were used as source of Cu, Zn, Mn, Fe and Zn-B respectively. From calibration of field spray of the trees, the volume of water required to completely wet the canopy of each tree was about 3 liters. The spray solution was prepared for each micronutrient in five well labeled 15 liters polyethylene containers at the rate of 214 orange trees ha^{-1} sprayed with 1.12kg each micronutrient in 640 liters of water according to the product recommendations. Accordingly, 26gm of each micronutrient per was added to 15 liters water and the solution was added to 15 L motorized sprayer and sprayed to each treatment plot. Water without micronutrient was applied to all the control plot trees to avoid the wetting effect difference of the orange trees due to spray. Detail of treatment combinations are given in Table 1.

DATA COLLECTION

Soil sampling

Soil samples were collected at two depths (0-45 cm and 45-90 cm) from experimental plots using graduated auger before treatment application. The soil sub-samples of each depth were mixed in plastic bags to make a total of two composite samples. Then the samples were labeled and transported to Melkassa Agricultural research Center (MARC) soil laboratory.

Leaf sampling

Six pre-treatment composite leaf samples (one per same treatment pooled from the three replication) were collected from medium portion of tagged shoots of the tree while eighteen post-treatment composite leaf samples were also collected 30 days after second foliar spray as recommended by Agrotech (1987). The number of sub-sample leaves per each tree was set to be around 10 from spring cycle growth of 4-8 months old having approximately the same size from non-fruit bearing terminals one to two meters above the ground. Diseased and injured leaves were discarded. Fruit yield parameters such as fruit weight and fruit quality parameters including percent total soluble sugar (TSS), percent fruit juice, juice pH, were also analyzed and recorded.

Laboratory analysis

The soil samples were air-dried, crushed with mortar and pestle, passed through 2 mm wire sieve for various physico-chemical parameters analysis. Air-dried orange leaves samples were ground with mortar and pestle to pass a 2 mm sieve. To avoid contamination, the samples were stored in plastic bags. The samples were again oven dried at 75 °C for 24 hours until it maintained constant weight and cooled in desiccators for 2 hour. 5g of each sample weighed before ashing. The oven dry samples described above was ashed by muffle raising the temperature slowly up to 450 °C (about 2.5h) and maintaining this temperature overnight. The ash samples were moistened with a few drops of water and covered with a watch glass for the determination of Cu, Fe, Mn, and Zn.

Soil texture, bulk density, pH, EC, total nitrogen, available phosphorus and organic carbon were determined at Melkassa Agricultural Research Center (MARC) soil laboratory. Other physical and chemical parameters of soil including (Field capacity) FC, Permanent wilting point (PWP), Exchangeable cations (K, Na, Ca, Mg), Cation exchange capacity (CEC), and Zinc (Zn), Copper (Cu), Iron (Fe) and Manganese (Mn) in leaf samples were determined at Debrezeyit Agricultural Research Center soil laboratory.

Particle size distribution of the soil samples was determined by hydrometer method (Bouyoucos, 1962). Soil bulk density was determined on the undisturbed core sampling method after drying the soil samples in an oven at 105°C to constant weights. The soil-water potential values were measured at -1/3 bar for field capacity (FC) and -15 bars for permanent wilting point (PWP) with pressure plate apparatus while available water holding capacity were obtained by subtracting PWP from FC (Klute, 1965).

Potentiometric method using a glass calomel combination electrode was used to measure pH of the soils in water suspension in a 1:2.5 (soil: water ratio) (Van Reeuwijk, 1992). Electrical conductivity (EC) was measured using a conductivity meter from the same soil water suspension extract. The Walkley and Black (1934) wet digestion method was used to determine soil organic carbon (OC) content. Total nitrogen content of the soil was determined by wet-oxidation procedure of the Kjeldahl method (Bremner and Mulvaney, 1982). Available P was determined using the standard Olsen *et al*. (1954) extraction methods. The absorbance of available P extracted was measured using spectrophotometer after colour development.

Exchangeable cations (Ca, Mg, K and Na) were determined after extracting the soil samples by 1N neutral ammonium acetate (1N NH_4OAc) solution adjusted to a pH 7.0. Exchangeable Ca and Mg in the extract were measured by atomic absorption

Table 1. Treatment setup.

No	Treatments	Other Fertilizers Kg ha^{-1}	Micro nutrient fertilizer product ha^{-1}				
			Fe	**Zn**	**Cu**	**Mn**	**B_Zn**
1	Control	146N, 138P_2O_5,51K_2O	--	--	--	--	--
2	Fe_1, Zn_0, Cu_0, Mn_0, $(Zn+B)_0$	146N, 138P_2O_5,51K_2O	**1.12**	--	--	--	--
3	Fe_0, Zn_1, Cu_0, Mn_0, $(Zn+B)_0$	146N, 138P_2O_5,51K_2O	--	**1.12**	--	--	--
4	Fe_0, Zn_0, Cu_1, Mn_0, $(Zn+B)_0$	146N, 138P_2O_5,51K_2O	--	--	**1.12**	--	--
5	Fe_0, Zn_0, Cu_0, Mn_1, $(Zn+B)_0$	146N, 138P_2O_5,51K_2O	--	--	--	**1.12**	--
6	Fe_0, Zn_0, Cu_0, Mn_0, $(Zn+B)_1$	146N, 138P_2O_5,51K_2O	--	--	--	--	**1.12**

Table 2. Soil physical property of Abadiska citrus farm

Depth	Sand	Clay	Silt	Textural. Class	BD (gm/cm^3)	FC (at -0.33bar)	PWP (at -15 bar)	TAWC
0-45	62	19	20	SL	1.20	28.30	9.30	19.00
45-90	66	24	10	SCL	1.22	32.26	15.12	17.14

BD = bulk density; FC = field capacity; PWP = permanent wilting point and TAWC = total available water content

Table 3. Soil chemical property of Abadiska citrus farm

Depth	PH- **H_2O (1:5)**	EC **(dS/m)**	Ols. P **(ppm)**	TN **(%)**	OC **(%)**	Exchangeable Cations (Cmol(+)/kg				CEC	PBS	ESP	Micronutrients (ppm)			
						Na	K	Ca	Mg				Cu	Fe	Mn	Zn
0-45	8.2	0.37	15.14	0.24	1.03	0.92	0.56	21.05	3.17	44.56	62.44	2.1	0.67	2.79	1.0	0.27
45-90	8.3	0.56	16.89	0.22	0.98	1.67	0.49	27.68	3.30	44.63	78.60	3.73	0.96	2.12	0.52	0.10

spectrophotometer (AAS) whilst K and Na were determined using flame photometer from the same extract (Okalebo et al., 2002). Cation exchange capacity of the soils was determined from the ammonium acetate saturated samples through distillation and measurement of ammonium using the modified Kjeldhal procedure as described by Okalebo et al. (2002). Micronutrients (Fe, Mn, Zn, Cu) in both soil and leaves samples were extracted by Di-ethyl Tri-amine Penta-acetic acid (DTPA) as described by Tan (1996) and all these micronutrients were measured by AAS.

Chemical quality of fruit such as % juice, TSS and juice pH were determined according to the method of AOAC, (1990). Fruit juice extracted by orange extractor and volume was measured in 100ml cylinder, juice pH was measured pH meter and TSS and sugar content were determined with a handheld refractometer.

DATA ANALYSIS

Standard values reported by Quaggio *et al*. (2010) were used as leaf analysis result guide for diagnosing nutrient status of mature Valencia orange trees. All the data collected during field and laboratory investigation were statistically analyzed using analysis of variance technique (Statsix 10) and the treatment differences were evaluated by Tukey test.

RESULTS AND DISCUSSION

Soil physic-chemical characteristics

The soil physical and chemical analysis result for this experiment are presented in Table 2 and Table 3 below. The textural classes of the soil at Abadiska orchid were found sandy loam for the top and sandy clay loam for the sub-soil (Table 2). The soils of the orchard was found calcareous in nature and moderately alkaline in the reaction as indicated in Table 3 (pH of 8.2-8.3) that potentially restrict most plant nutrients availability mainly micronutrients as also depicted by Zakir et al. (2003). The values of EC for the study site ranged from 0.37 dS m^{-1} to 0.56 dS m^{-1} (Table 3) showed no salinity problem according to the standards given by Richards (1954).

The soil under the orchard was found low in organic carbon content (Table 3) according to the standards given by (Charman et al., 2007). Total nitrogen, available phosphorus, cation exchange capacity (CEC) and most exchangeable cations except potassium were at high level, according to the standards reported by Bruce and Rayment (1982), Clements et al. (1994) and FAO (2006). The extractable micronutrients contents of soil depicted deficiency of Cu and Zn while Mn and Fe were found adequate according to the standards reported by Jones, (2003) and Marx *et al*. (1999). Similar findings were reported form soil micronutrient assessments done in the

Table 4. Leaf analysis result of orange trees (cv. *Valencia*) before treatment application (in mg kg^{-1})

	Cu	Fe	Mn	Zn
Range (n=6)	2.0-8.8	102.5-120.1	25.6-45.0	12.3-17.3
Mean± SD	4.30 ±2.97	115.08± 6.57	33.68 ±7.50	14.22 ±2.41

n=Frequency

Table 5. Leaf analysis result of orange trees (cv. *Valencia*) before and after treatment application

Micronutrient (mg kg^{-1})	Before foliar spray	After foliar spray	Standard leaf concentration (Quaggio *et al*., 2010)		
			Low	Optimum	High
Fe	115.08	146.8	<49	50-120	>200
Zn	14.22	49.2	<34	35-50	>100
Cu	4.30	21.1	<10	10-20	>20
Mn	33.68	80.5	<34	35-50	>100

Table 6. Effect of foliar application of micronutrients on leaf micronutrient content of orange cv. *Valencia*

Treatment	Fe (mg kg^{-1})	Zn	Cu	Mn
1. Control	71.8^{bc}	16.3^{c}	4.8^{b}	53.0
2. Fe 13.2%	146.8^{a}	18.1^{c}	3.3^{b}	47.3
3. Zn 14%	96.8^{bc}	49.2^{a}	5.8^{b}	38.7
4. Cu 14%	70.8^{bc}	17.9^{c}	21.1^{a}	46. 7
5. Mn 13%	105.0^{ab}	16.4^{c}	5.7^{b}	80.5
6. Zn 4 %+B 2%	55.7^{c}	36.9^{b}	4.1^{b}	53.0
CV (%)	16.2	10.9	23.3	29.0
LSD	41.9	7.9	7.1	ns

UAAIR citrus farm (Dejene, 2009).

Micronutrient concentrations in leaves of orange trees before foliar spray

The concentrations of micronutrients (Fe, Zn, Cu and Mn) in orange leaves before treatment application is summarized in Table 4. The leaf analysis result revealed that Zn and Cu concentrations were found deficient while, manganese concentration was found adequate. Iron was found in the optimum range. These were evaluated on the basis of criteria reported by Quaggio *et al*. (2010) as indicated in table 5.

Micronutrient concentrations in leaves of orange trees after foliar spray

The analysis data shown in Table 5 revealed that foliar application of iron, zinc and copper on orange trees *cv. Valencia* significantly increased leaf iron, zinc and copper contents ($p < 0.05$) as compared to leaves from trees not treated with iron, zinc and copper.

The result clearly indicated that Zn and Cu contents in orange leaves were increased to the optimum range while Fe and Mn concentrations were above optimum range when they were applied in foliar (Table 5). The finding of this experiment is congruent with the finding by Mann *et al*. (1985) that showed foliar spray of micronutrients on the leaves of oranges increased the concentration of these nutrients in the leaves. As compared to the control, mean values of Fe, Zn and Cu concentrations in leaf showed an increase from 71.8 to 146.8 mg kg^{-1}, 16.3 to 49.2 mg kg^{-1} and 4.8 to 21.1 mg kg^{-1} respectively in the treatments where Fe, Zn and Cu were applied (Table 6). These increases in leaf Fe, Zn and Cu content was due to absorption from foliar spray and translocation to leaves (Mann *et al*,. 1985). All trees in plots treated with Mn showed improved leaf Mn content (53 to 80.5 mg kg^{-1}) but not significantly as compared to the control.

Table 7. Orange fruit cv. *Valencia* yield as affected by the application of micronutrients

Treatments	Fruit weight (Mt ha^{-1})	Increase %
Control	16.81^{c}	-
Iron	21.02^{abc}	25.04
Zinc	22.99^{ab}	36.76
Copper	22.04^{abc}	31.11
Manganese	25.32^{a}	50.09
Zinc+ Boron	17.89^{bc}	6.42
Iron	NS	
Zinc	*	
Copper	NS	
Manganese	*	
Zinc+ Boron	NS	

NS= None significance at p<0.05, * significance at p<0.05

Table 8. Effects of micronutrients on average fruit weight (Av.FW) (g), sugar content (%) and juice (%) of cv. *Valencia*

Treatment	Av. FW	Sugar	Juice%
Control	155.8	80	38.11
Iron	169.45	84	40.36
Zinc	174.45	78.33	39.67
Copper	171.21	79.67	39.71
Manganes	164.87	76.33	43.4
Zinc+Copper	160.63	82	41.43
CV	8.36	8.05	9.53
LSD	ns	ns	ns

Effect of micronutrients on yield and quality parameters of orange fruit

Foliar application of micronutrients on orange trees increased significantly the fruit yield as compared to control (Table 7). Iron, Zinc, Copper and Manganese application showed a yield increase of 25.04%, 36.76%, 31.11% and 50.62% (Table 7) respectively as compared to yield obtained from the control, demonstrating foliar application of micronutrients improving fruit yield. Similar finding was reported by Tariq et al.(2007) that indicated foliar application of Mn caused 49.97% and Zn + Mn caused 95.70% increased over the control. Similarly, Hafeez et al. (2006*)* and Chiu et al. (1986) also reported that foliar application of micronutrients improved fruit yield. Increase in leaf concentration of Mn was not significant (p<0.05), however, the leaf concentration increase was observed in all plots sprayed with Mn, that in turn induces more flowering and minimized the late drop of fruits in Valencia orange trees. These results is also in line with Gracia *et al*. (1984) that showed decreased late dropping of immature fruits as leaf Zn and Mn content increased.

Table 8. Showed that Fruit weight, sugar contents and juice percent of the Valencia orange was increased by the foliar application of micronutrients. Average fruit weight was increased by 11.9% due to foliar application of Fe when compared with the control. The application of Iron, Manganese and Zinc+Boron increased the juice % by 5.9, 13.9 and 8.7% respectively. Also the increase of sugar content as indicated in (Table 8) was about 2.5 and 5% due to application of Zinc + Boron and Iron, respectively when compared to the control though, statistically not significant. Mann et al (1985) and Tariq et al (2007) also reported that micronutrients foliar application had no significant effect on the quality parameters of citrus fruits.

Foliar application of micronutrients at concentration of 1.12 kg ha^{-1} resulted in some fruit quality improvements. As Fig.1 revealed total soluble solids (TSS) increased from 3.7 to 14.8% by the foliar application of micronutrients when compared with the control. This

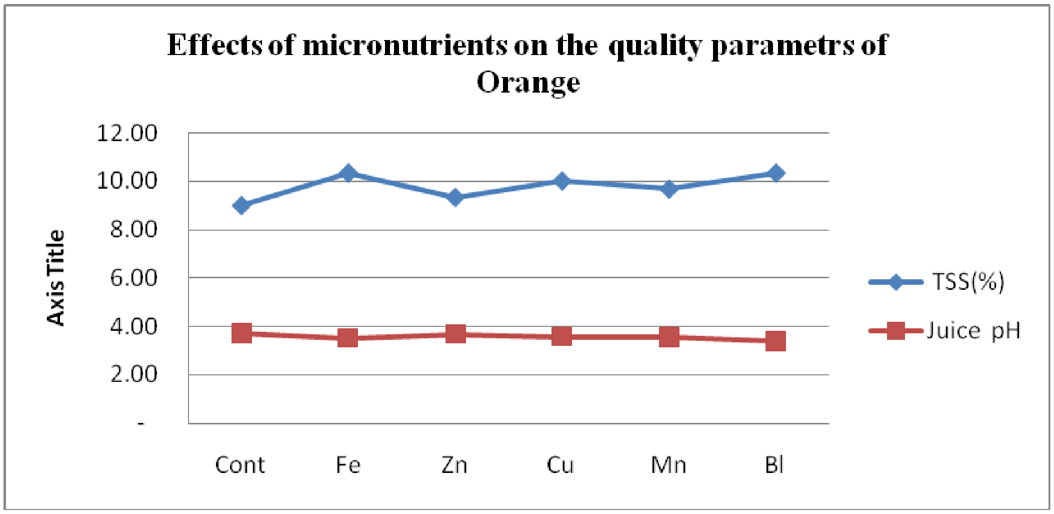

Figure 1. Effects of foliar spray of micronutrients on juice pH and TSS of cv. *Valencia* fruit.

result is also in agreement with Yara report (2016) that showed application of iron has a direct effect on fruit quality improving the levels of TSS in oranges & mandarins.

Spray of micronutrients decreased the juice pH in the Abadska Orchid when compared to the control however the decrease was statistically not significant (Figure 1). From visual observation of the field, the micro nutrient applied orange plants were found green and look healthy. This was in agreement with the plant leaf nutrient status that subsequently enhanced the fruit yield of orange.

CONCLUSION AND RECOMMENDATIONS

On the basis of present study, it is revealed that citrus orchard at Abadiska, Upper Awash Agro-Industry Enterprise, responded well to foliar applications of micro-nutrients. Foliar application of Zn and Mn significantly increased the fruit yield of the Abadiska orchid when compared to the control as a result of improved leaf micronutrients status of the orange trees. The increase in Mn content in leaf samples of the orange trees sprayed with Mn was not significant; however it was higher in all Mn sprayed plots. Foliar application of micronutrients at concentration of 1.12 kg ha^{-1} also improved the fruit qualities including TSS, average fruit weight and sugar content as compared to the control.

Hence, it is recommended to conduct further research to identify adequate rates for combinations of micronutrients in order to get high quality fruit production. Such practice of fertilization on regular basis will not only improved the fruit yield but also extend the bearing life of the existing citrus orchard in the country. Further research for the determination of economic rate of application for the combined use of the deficient micronutrients is required to improve the production and quality of orange.

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