Full Length Research

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


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 (Asgellil 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 (CaCO₃) 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 (Álvarez-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 (Asgeilik 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 Shewa zone at some 200 kms from Addis Ababa near Merti processing plant at the latitude of 8° 34' 15.4''N and 39° 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 °C and 14 °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 P₂O₅ ha⁻¹ from .urea and DAP, the enterprise agricultural practices, 51 kg K₂O 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 NH₄OAc) solution
adjusted to a pH 7.0. Exchangeable Ca and Mg in the
extract were measured by atomic absorption
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 physico-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 1. Treatment setup.

<table>
<thead>
<tr>
<th>No</th>
<th>Treatments</th>
<th>Other Fertilizers Kg ha(^{-1})</th>
<th>Micro nutrient fertilizer product ha(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Control</td>
<td>146N, 138P(_2)O(_5), 51K(_2)O</td>
<td>Fe --- Zn --- Cu --- Mn --- B (_{Zn}) ---</td>
</tr>
<tr>
<td>2</td>
<td>Fe(<em>{0}), Zn(</em>{0}), Cu(<em>{0}), Mn(</em>{0}), (Zn+B)(_{0})</td>
<td>146N, 138P(_2)O(_5), 51K(_2)O</td>
<td>Fe 1.12 Zn --- Cu --- Mn --- B (_{Zn}) ---</td>
</tr>
<tr>
<td>3</td>
<td>Fe(<em>{0}), Zn(</em>{0}), Cu(<em>{0}), Mn(</em>{0}), (Zn+B)(_{0})</td>
<td>146N, 138P(_2)O(_5), 51K(_2)O</td>
<td>Fe --- Zn 1.12 Cu --- Mn --- B (_{Zn}) ---</td>
</tr>
<tr>
<td>4</td>
<td>Fe(<em>{0}), Zn(</em>{0}), Cu(<em>{0}), Mn(</em>{0}), (Zn+B)(_{0})</td>
<td>146N, 138P(_2)O(_5), 51K(_2)O</td>
<td>Fe --- Zn --- Cu 1.12 Mn --- B (_{Zn}) ---</td>
</tr>
<tr>
<td>5</td>
<td>Fe(<em>{0}), Zn(</em>{0}), Cu(<em>{0}), Mn(</em>{0}), (Zn+B)(_{0})</td>
<td>146N, 138P(_2)O(_5), 51K(_2)O</td>
<td>Fe --- Zn --- Cu --- Mn 1.12 B (_{Zn}) ---</td>
</tr>
<tr>
<td>6</td>
<td>Fe(<em>{0}), Zn(</em>{0}), Cu(<em>{0}), Mn(</em>{0}), (Zn+B)(_{0})</td>
<td>146N, 138P(_2)O(_5), 51K(_2)O</td>
<td>Fe --- Zn --- Cu --- Mn --- B (_{Zn}) 1.12</td>
</tr>
</tbody>
</table>

### Table 2. Soil physical property of Abadiska citrus farm

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

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

<table>
<thead>
<tr>
<th>Depth</th>
<th>PH(_{H_2O}) (1:5)</th>
<th>EC (dS/m)</th>
<th>Ols. P (ppm)</th>
<th>TN (%)</th>
<th>OC (%)</th>
<th>Exchangeable Cations (Cmol(+)/kg)</th>
<th>CEC</th>
<th>PBS</th>
<th>ESP</th>
<th>Micronutrients (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-45</td>
<td>8.2</td>
<td>0.37</td>
<td>15.14</td>
<td>0.24</td>
<td>1.03</td>
<td>0.92 Na 0.56 K 21.05 Ca 3.17 Mg</td>
<td>44.56</td>
<td>62.44</td>
<td>2.1</td>
<td>Cu 0.67 Fe 2.79 Mn 1.0 Zn 0.27</td>
</tr>
<tr>
<td>45-90</td>
<td>8.3</td>
<td>0.56</td>
<td>18.89</td>
<td>0.22</td>
<td>0.98</td>
<td>1.67 Na 0.49 K 27.68 Ca 3.30 Mg</td>
<td>44.63</td>
<td>78.60</td>
<td>3.73</td>
<td>Cu 0.96 Fe 2.12 Mn 0.52 Zn 0.10</td>
</tr>
</tbody>
</table>
**Table 4. Leaf analysis result of orange trees (cv. Valencia) before treatment application (in mg kg⁻¹)**

<table>
<thead>
<tr>
<th>Micronutrient</th>
<th>Cu Range (n=6)</th>
<th>Fe Mean ± SD</th>
<th>Mn Mean ± SD</th>
<th>Zn Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu</td>
<td>2.0-8.8</td>
<td>102.5-120.1</td>
<td>25.6-45.0</td>
<td>12.3-17.3</td>
</tr>
<tr>
<td>Mn</td>
<td>4.30 ±2.97</td>
<td>115.08 ± 6.57</td>
<td>33.68 ±7.50</td>
<td>14.22 ±2.41</td>
</tr>
</tbody>
</table>

n=Frequency

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

<table>
<thead>
<tr>
<th>Micronutrient (mg kg⁻¹)</th>
<th>Before foliar spray</th>
<th>After foliar spray</th>
<th>Standard leaf concentration (Quaggio <em>et al.</em>, 2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>115.08</td>
<td>146.8</td>
<td>Low (&lt;49) 50-120 High (&gt;200)</td>
</tr>
<tr>
<td>Zn</td>
<td>14.22</td>
<td>49.2</td>
<td>Low (&lt;34) 35-50 High (&gt;100)</td>
</tr>
<tr>
<td>Cu</td>
<td>4.30</td>
<td>21.1</td>
<td>Low (&lt;10) 10-20 High (&gt;20)</td>
</tr>
<tr>
<td>Mn</td>
<td>33.68</td>
<td>80.5</td>
<td>Low (&lt;34) 35-50 High (&gt;100)</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fe mg kg⁻¹</th>
<th>Zn mg kg⁻¹</th>
<th>Cu mg kg⁻¹</th>
<th>Mn mg kg⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Control</td>
<td>71.8 bc</td>
<td>16.3 c</td>
<td>4.8 b</td>
<td>53.0</td>
</tr>
<tr>
<td>2. Fe 13.2%</td>
<td>146.8 a</td>
<td>18.1 c</td>
<td>3.3 b</td>
<td>47.3</td>
</tr>
<tr>
<td>3. Zn 14%</td>
<td>96.8 bc</td>
<td>49.2 a</td>
<td>5.8 b</td>
<td>38.7</td>
</tr>
<tr>
<td>4. Cu 14%</td>
<td>70.8 bc</td>
<td>17.9 c</td>
<td>21.1 b</td>
<td>46.7</td>
</tr>
<tr>
<td>5. Mn 13%</td>
<td>105.0 abc</td>
<td>16.4 c</td>
<td>5.7 b</td>
<td>80.5</td>
</tr>
<tr>
<td>6. Zn 4 %+B 2%</td>
<td>55.7 c</td>
<td>36.9 b</td>
<td>4.1 b</td>
<td>53.0</td>
</tr>
<tr>
<td>CV (%)</td>
<td>16.2</td>
<td>10.9</td>
<td>23.3</td>
<td>29.0</td>
</tr>
<tr>
<td>LSD (%)</td>
<td>41.9</td>
<td>7.9</td>
<td>7.1 ns</td>
<td></td>
</tr>
</tbody>
</table>

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.
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

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

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Fruit weight (Mt ha⁻¹)</th>
<th>Increase %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>16.81</td>
<td>-</td>
</tr>
<tr>
<td>Iron</td>
<td>21.02&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>25.04</td>
</tr>
<tr>
<td>Zinc</td>
<td>22.99&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>36.76</td>
</tr>
<tr>
<td>Copper</td>
<td>22.04&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>31.11</td>
</tr>
<tr>
<td>Manganese</td>
<td>25.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>50.09</td>
</tr>
<tr>
<td>Zinc+ Boron</td>
<td>17.89&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>6.42</td>
</tr>
<tr>
<td>Iron</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Manganese</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Zinc+ Boron</td>
<td>NS</td>
<td></td>
</tr>
</tbody>
</table>

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*

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Av. FW</th>
<th>Sugar</th>
<th>Juice%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>155.8</td>
<td>80</td>
<td>38.11</td>
</tr>
<tr>
<td>Iron</td>
<td>169.45</td>
<td>84</td>
<td>40.36</td>
</tr>
<tr>
<td>Zinc</td>
<td>174.45</td>
<td>78.33</td>
<td>39.67</td>
</tr>
<tr>
<td>Copper</td>
<td>171.21</td>
<td>79.67</td>
<td>39.71</td>
</tr>
<tr>
<td>Manganese</td>
<td>164.87</td>
<td>76.33</td>
<td>43.4</td>
</tr>
<tr>
<td>Zinc+Copper</td>
<td>160.63</td>
<td>82</td>
<td>41.43</td>
</tr>
<tr>
<td>CV</td>
<td>8.36</td>
<td>8.05</td>
<td>9.53</td>
</tr>
<tr>
<td>LSD</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

Effect of micronutrients on yield and quality parameters of orange fruit...
The results are in agreement with Yara report (2016) that showed the 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 Abadiska Orchard 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 micronutrients. Foliar application of Zn and Mn significantly increased the fruit yield of the Abadiska orchard 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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