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MITIGATION OF HEAT STRESS EFFECTS USING AGRICULTURAL TREATMENTS ON GROWTH, YIELD AND FRUIT QUALITY OF WASHINGTON NAVEL ORANGE TREES GROWN IN EGYPT

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Abstract

High temperature stress can be detrimental to citrus trees, resulting in a lack of fruit yield and an increase of fruit disorders. One strategy that farmers can use to maintain or increase their yields to face the climate change, is to adjust the farm climate by growing an Intercrop *Moringa oleifera* seedling on the inter-row space of Washington navel orange trees which protects the citrus trees from direct sun and may mitigates the additional heat reflected from the soil, also, provides an additional benefit in the form of crop diversification, which may contribute to economic resilience for growers. Such, we used a one-year old moringa seedlings transplanted as a shade cover and a shade trellis structure for Washington navel orange (*Citrus sinensis* L. Osbeck) trees planted in Al Nubaria region, Egypt. Growth (number of shoots/one meter branch, number of leaves/shoot, shoot length, leaves chlorophyll content, leaf area and tree canopy), and leaves macronutrients (N, P, K, Ca, Mg) and micronutrients (Fe, Zn, Mn, Cu, Na) content, and fruit characteristics (number, weight, diameter, peel thickness, total soluble solids, total acidity and ascorbic acid), and yield and crop efficiency of orange trees were determined. It can be recommended that using the trellis for shading to reduce the effect of heat stress on Washington navel orange trees gave the largest number of fruits, which led to more efficient distributed yield on the trees, followed in ascending order by Moringa seedlings cultivation among the rows of Washington navel orange trees comparing to uncovered orange trees in the field.
***Keywords* :** Crop efficiency, intercropping moringa, nutrients status, trellis.

Introduction

Citrus production in hot season is difficult due to high temperatures and excessive radiation. Washington navel orange tree is the most important of all citrus fruits in Egypt. It represents a larger area than all other varieties. It is practically more sensitive to environmental stresses such as microclimate stability which is reflected on yield reduction. Production under tree shade can assist by modifying the microclimate in two main ways: reduction of temperature caused by direct sunlight and minimization of radiation load (Chandiposha, 2007 and Mahmood *et al*., 2018). Whilst artificial shade is expensive, tree shade is both cheaper and more practical (Chandiposha, 2007). Generally, shading causes reduction of temperature and temperature fluctuations together with vapor pressure deficit (VPD) under tropical conditions (Nair, 1993).

Intercropping with some trees promoted the net profit, and at the same time, it had no considerable adverse effects on the yield and fruit quality of the main crops (Abouziena *et al*., 2010), so, it is possible to grow a mixed fruit orchard such as date palm intercropped with citrus (Mortan, 1987). Intercropping may provide an additional benefit in the form of crop diversification, which may contribute to economic resilience for growers. Examples can be drawn from Barradas and Fanjul (1986) who discovered coffee plantations under shade of *Inga jinicuil*. Similar results indicating microclimate amelioration were reported for a combination of coconut and cacoa in India (Nair and Balakrishnan, 1977). Also, tea yields have been increased under shade in Tanzania during the dry season (Willey, 1975).

The ideal shade tree should have a sparse, small crown to permeate sunlight (Chundawat and Gautam, 1993). Potentially *Moringa oleifera* can be used for shade under semi-arid conditions since it has an open crown that can allow radiation to penetrate under storey crops (Nair, 1993). A common way of cultivating the moringa trees in both Southern Ethiopia and Kenya was growing it with other staple food crops such as cassava, maize and sorghum (Kumassa *et al*., 2017). In addition, moringa is a drought-tolerant tree most suitable for semi-arid conditions (Palada and Chang, 2003). Legumes performed better under moringa trees than vegetables (Motisa *et al*., 2017). Rape/moringa stands led to the reduction in weed densities and weed biomass, and at the same time increased gravimetric moisture levels. Based on these results, rape/moringa mixtures are recommended as they are more productive, giving greater biomass outputs than sole rape (Chandiposha, 2007). Moringa is a multi-purpose tree with many benefits including fencing, wind protection, and support for climbing garden plants. In addition, moringa has high levels of vitamin A and C, protein and minerals such as iron and calcium. Other uses of moringa include oil extraction and water purification (Price, 2000). The Moringa leaves shed on the soil serve as green manure to increase soil fertility and boost crop yield.

Moringa trees can be planted in gardens; the tree's root system does not compete with other crops for surface nutrients and the light shade provided by the tree will be beneficial to those vegetables which are less tolerant to direct sunlight, as also moringa is resistant to most pests and have been found to suppress the population of phytonematodes by releasing nematotoxins into the soil when grown with susceptible crops, and/or used their extracts (Claudius-Cole *et al*., 2010).

Trellis can be referred to as panels, usually made of interwoven wood pieces attached to fences or the roof or exterior walls of a place. There are many types of trellis for different places and plants, from agricultural types, especially in viticulture, which are covered at vine training systems, and it was used to support shrubs in espalier, also to separate roads from thickets and diverse sections of vegetable gardens (Simpson, 2016).

It is important to establish suitable cover cropping in the inter-row space, which under this condition reflects bare earth and dead vegetation, therefore, moringa intercropping reflects more sunlight into the orchard canopy than green vegetation.

The purpose of this study was to evaluate the effect of moringa as a shade tree or trellis application on mitigation of heat stress effects and its reflection on vegetative growth characteristics, yield and fruit quality of Washington navel orange trees.

Material and Methods

Healthy and uniform Washington navel orange (*Citrus sinensis* L. Osbeck) trees grafted on volkamer lemon rootstock (*C. volkameriana,* L), were about twelve years old, planted in a system of 3.5 x 5 meters, and grown on sandy soil in the National Research Centre farm for research and production in Al-Emam Malek village, Al-Nubaria region, Al-Behira Governorate, Egypt (its location is latitude 30^o 30' 1.4" N, and longitude 30^o 19' 10.9" E, and mean altitude 21m above sea level), were tested to reduce the effect of heat stress on trees by protecting the set of fruit and improving productivity and quality in sandy soil.

Trellis shade is manufactured from knitted polyethylene fabric that does not rot, mildew or become brittle. It can be used for canopies and farm stands, easy to install and remove. Trellis is an architectural structure, made from intersecting pieces of Casuarina columns. The first steps to create the structure for trellis were done by digging holes, placing Casuarina columns with five-meters high, then tightening the wire on them, then covering with the white net (about 25 % shading of the light intensity), only in the (east - west) directions to ensure sufficient sunlight and airflow to protect the fruit set then growth and production. *Moringa oleifera* Lam (obtained from the Egyptian Scientific Association for Moringa, National Research Centre, Egypt) seedlings were transplanted at the end of February 2017 into holes of 15 cm deep and at a spacing of 1m. When the seedlings reached a height of 120 cm, the terminal growing tip was pinched 10 cm from the top using fingers since the terminal growth is tender, devoid of bark fiber and brittle, and therefore easily broken. Moringa responds well to pruning, regular pruning and leaf harvesting, therefore, it would likely result in sufficient light below the canopy which allow using it as a cover crop (Crosby and Craker, 2007). Secondary branches began appearing on the main stem below the cut one week later. When they reached 20 cm length, they were cut back to 10 cm using a sharp blade by making a slanted cut. When the tertiary branches appeared, pruning of moringa trees had reduced the heat stress negative effects as noted by Nair (1993). During its first year, moringa trees grew up to 2-3 meters in height and the trees were cut back annually to two meters from the ground. The trees were quickly recovered and produced leaves. At each harvest time, main branches were cut to a height of 2 m, and the leaves were stripped off and collected from pruned branches (Palada *et al.*, 2008). Pruning of shade trees enables the farmers to use the leaves as food, fodder or medicine. The other horticultural practices were similar for all orange trees as recommended from National Campaign for Improving Citrus Productivity in Egypt. Drip irrigation system was installed to irrigate all trees. Each treatment was replicated three times in a randomized complete block design. Each replication consisted of a row of moringa trees or trellis structure divided into 10 m long plots comparing with uncovered orange trees. Soil sample was analyzed at the beginning of the work (Table 1) for texture, pH and electrical conductivity (EC) using water extract (1:2.5) method, total calcium carbonate ($CaCO_3$%) using calcimeter method and organic matter (O.M.%) using potassium dichromate (Chapman and Pratt, 1978). Phosphorus was extracted using sodium bicarbonate (Olsen *et al*., 1954). Potassium (K), calcium (Ca), magnesium (Mg) and sodium (Na) were extracted using ammonium acetate (Jackson, 1973). Iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) were extracted using DPTA (Lindsay and Norvell, 1978).

Table 1: Soil sample was analyzed at the beginning of the work

Sand %	92.6	Ca (mg/100g)	286
Clay %	4.6	Mg (mg/100g)	29.2
Silt %	2.8	Na (mg/100g)	29.6
Texture	Sandy	K (mg/100g)	9.34
E C (ds/m)	0.41	$CaCO_3$ (%)	1.2
pH	8.25	Fe (mg/kg)	16.4
O.M.%	0.48	Mn (mg/kg)	4.8
Total N (mg/100g)	14.8	Zn (mg/kg)	0.9
Available P (mg/100g)	1.56	Cu (mg/kg)	0.4

Measurements

Growth and yields: in early September, leaf area was measured using the formula of 0.608 constant x (maximum leaf length x maximum leaf breadth) according to Shrestha and Balakrishnan (1985). Number of shoots/one-meter branch, Number of leaves/shoot and shoot length were measured. Chlorophyll content was measured as CCI (Chlorophyll Content Index) using Chlorophyll content Meter 003109 (CCM-200 plus Opti -Sciences). At commercial harvesting stage (color break) in early December, yield as weight and number of fruits per tree were recorded. Canopy volume of the tree was measured in early December as the tree shape was considered as one-half of a probate sphere (volume = 4/6 x π x height x radius2 "which π = 22/7") recorded as described by Roose *et al*., (1989). Cropping efficiency was calculated by dividing the fruit yield weight by the canopy volume according to Whitney *et al*., (1995).

Leaf mineral composition: leaf samples were collected according to (Jones and Embleton, 1960), then washed, dried at 70 °C until a constant weight , ground and digested using an acid mixture consisting of nitric, perchloric and sulfuric acids at ratio of 8:1:1 (v/v), respectively according to (Chapman and Pratt,1978). Nitrogen was estimated by semi-micro Kjeldahl method of (Plummer, 1971). Phosphorus was determined using a spectrophotometer at 882-OVV by the method outlined by Jackson (1973). Potassium, calcium and sodium were determined by a flame photometer "Jenway PFP7". Magnesium, iron, manganese, zinc and copper were determined using atomic absorption Spectrophotometer "Perkin Elmer 1100" (Cottanie, *et al*., 1982). These measurements were performed in the Agricultural Services Unit and Laboratory Analysis of Research Project

(Micronutrients and Other Plant Nutrition Problems in Egypt) in the National Research Centre.

Fruit quality: ten fruits were randomly sampled per each tree to estimate weight, diameter and peel thickness, then from the juice to estimate total soluble solids percentage (T.S.S Brix %) using Carl Zeiss hand refractometer, total acidity as anhydrous citric acid %, and vitamin C was estimated as mg ascorbic acid per 100 ml Juice according to (A.O.A.C., 1995).

Statistical analysis: The data obtained in each season were analyzed by ANOVA according to (Snedecor and Cochran, 1982) using Statistix 8.1 software. The means were separated by Duncan's (1955) multiple range test using a significance level of $P<0.05$.

Results

Figure (1) shows the effect of applied agricultural treatments to reduce the effect of heat stress on growth of Washington navel orange trees grown in sandy soil. The cultivation of moringa seedlings as an intercrop and shade tree or trellis as a shading structure resulted in a significant increase of orange tree shoots number especially in the first season compared to the control trees, and using moringa seedling gave the highest leaf chlorophyll content especially in the second season. While, using trellis for shading significantly increased the number of leaves/shoot in the first season and shoot length in the second season compared to control trees. Differences in the other vegetative growth characteristics were light and insignificant.

Figure (2) shows that some of the agricultural operations led to the fact that (I) all elements were in the optimal ranges of healthy orange leaf. (II) the resulting leaves contained macronutrients (nitrogen, phosphorus and potassium), which were significantly higher than the control trees, except the phosphorus which was higher than those limits under all types of coverage. The leaves of the trees growing under the shade of moringa seedlings contained the highest content of phosphorus and potassium, while those grown under trellis shade contained similar nitrogen and highest potassium content in the second season, and highest magnesium content in the first season, while, the rest of differences in the elements were mild and insignificant.

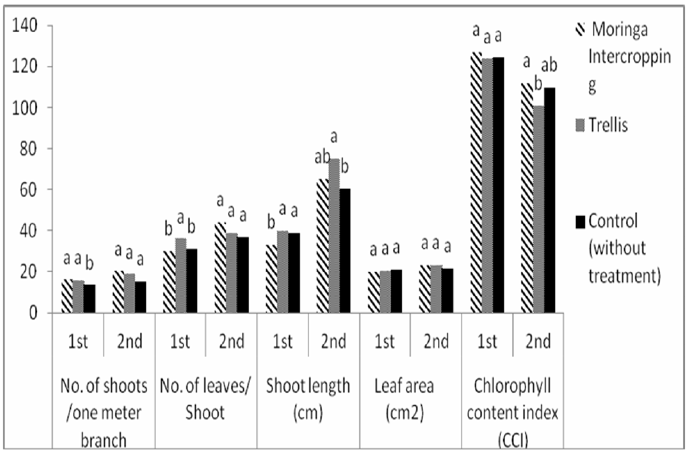


Fig. 1: Mitigation of heat stress effects using agricultural treatments on vegetative growth characteristics and chlorophyll content of Washington navel orange trees during 2017 and 2018 seasons.

Values followed by the same letter/s over each column didn't significantly differ at 5% level.

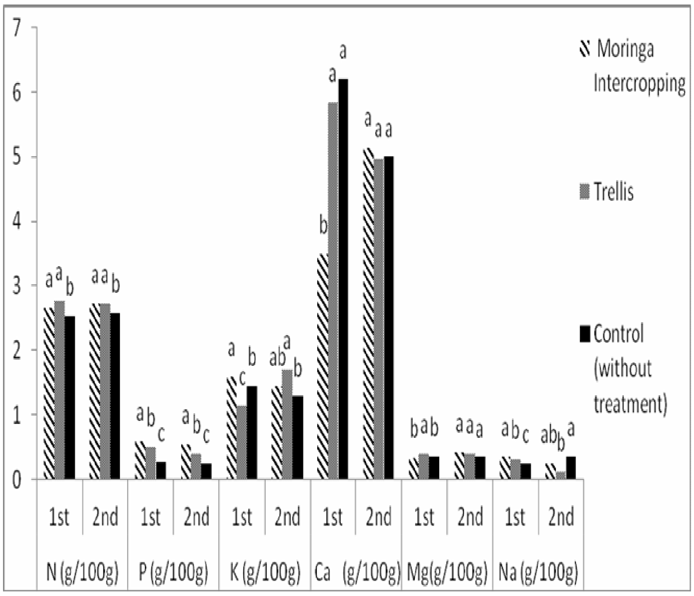


Fig. 2: Effect of some agricultural treatments on Washington navel orange leaf minerals content during 2017 and 2018 seasons.

Values followed by the same letter/s over each column didn't significantly differ at 5% level.

Figure (3) shows that all elements were in the optimal ranges of the healthy orange leaf and the cultivation of moringa seedlings as an intercrop and a shading tree influenced a high content of orange leaves micronutrient elements. The leaves contained the highest ratio of Iron and manganese in the two seasons, and copper in the second season, and sodium in the first season. The effect of trellis for shading was second, and the leaves contained less zinc, copper and sodium especially in the second season comparing with the other treatments. Differences in the other elements were light and insignificant.

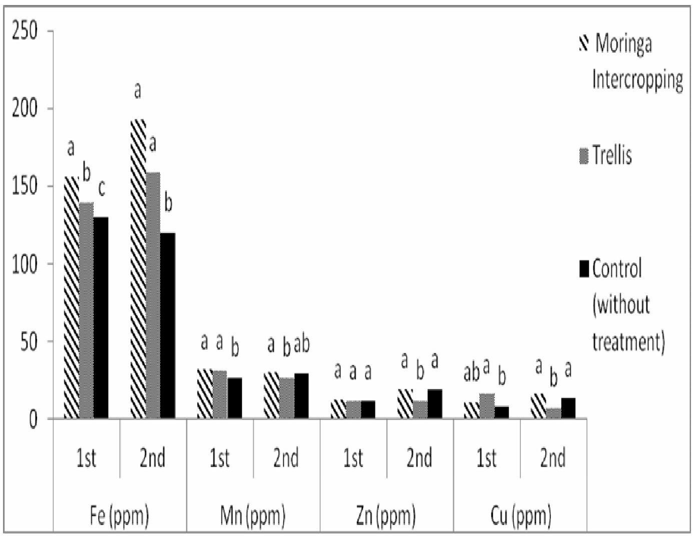
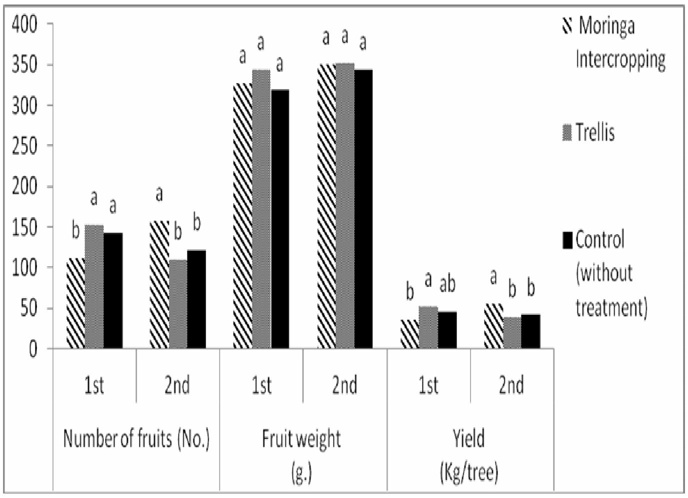
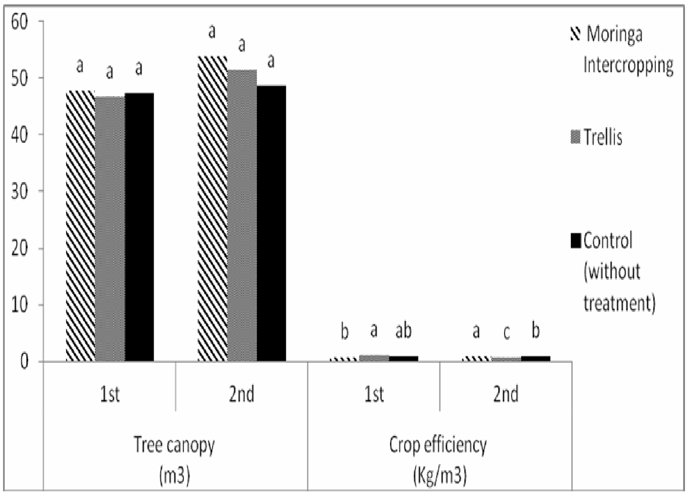


Fig. 3: Effect of some agricultural treatments on Washington navel orange leaf minerals content during 2017 and 2018 seasons.

Values followed by the same letter/s over each column didn't significantly differ at 5% level.



(A)

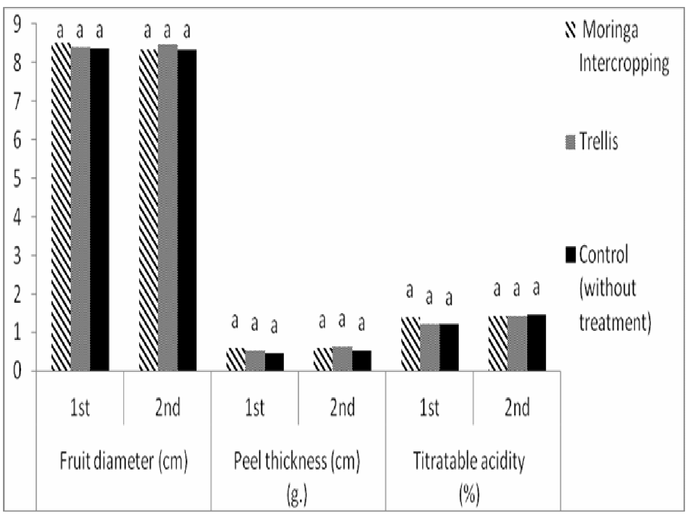


(B)

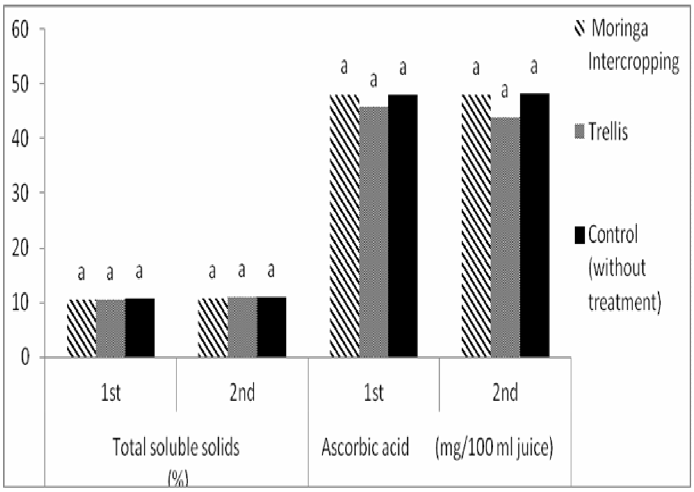
Fig. 4 : Mitigation of heat stress effects using some agricultural treatments on yield and its components of Washington navel orange trees during 2017 and 2018 seasons.

Values followed by the same letter/s over each column didn't significantly differ at 5% level.

Figure (4 A and B) shows that the highest yield during the first season resulted from shade trellis structure, which also gave the largest number of fruits and led to the highest efficiency of the crop, however, in the second season, the highest yield was obtained by moringa as an intercrop. All treatments were significantly equal in its fruit weight and the canopy of trees.



(A)



(B)

Fig. 5: Mitigation of heat stress effects using agricultural treatments on fruit characteristics of Washington navel orange during 2017 and 2018 seasons.

Values followed by the same letter/s over each column didn't significantly differ at 5% level.

Figure (5 A and B) shows that both shading treatments did not affect the quality of orange fruits (fruit diameter, peel thickness, total soluble solids, total acidity and vitamin C content), where all differences were insignificant.

Discussion

Citrus production under heat stress is difficult due to high temperatures and excessive radiation, therefore, differences in the other vegetative growth characteristics were light and insignificant although the importance of light in the production of ATP and NADPH and thus at low light intensities, these products are not produced in adequate amounts (Acquaah, 2005), and this will also result in a lack biomass accumulated over time (Loomis and Amthor, 1999). In semi-arid regions, the transpiration of shade trees may actually increase water stress to the understorey crops (Nair, 1993). When plants grow under conditions of moisture stress because of low soil moisture, enzymatic activities associated with photosynthesis in the plants slow down. Stomata close under moisture stress, reducing carbon dioxide availability and consequently decreasing photosynthetic rate (Acquaah, 2005). In this regard, Ilic and Fallik (2017) concluded that accumulation of phytochemicals during the production of plants depends on many factors such as light quantity and quality, type of varieties or cultivars, growing season and metabolic factors. Marouelli and Silva (2005) and also Jutamanee and Ommon (2016) indicated that shading mango trees can be an effective technique to avoid undesirable effects of excess solar irradiation under hot climate. Thus, Zhou *et al*. (2018) observed faster vegetative growth induced by netting treatments, as that, photosynthesis and stomata conductance were affected differently between annual seasons over treatments.

All macro elements were in the optimal ranges of the healthy orange leaf according to Werner (1992), who noted that adequate ranges for citrus leaf as percentage were: 2.4 - 3.5 (N), 0.15 - 0.3 (P), 1.2 - 2.0 (K), 3 - 7 (Ca), 0.25 - 0.7 (Mg). Shading technology in some locations confirmed a general decrease of maximum daily temperature (T. max) by 1 - 5 °C, followed by an increase in maximum daily relative air humidity by approximately 3 – 10 % (Ignasi and Alegre, 2006). So, shade altered sunlight intensity with relatively little effect on air temperature. Moringa trees can be planted in gardens; the tree's root system does not compete with other crops for surface nutrients and the light shade provided by the tree will be beneficial to those plants which are less tolerant to direct sunlight. Moringa plants have been found to suppress the population of Phyto nematodes by releasing hematotoxins into the soil when grown with susceptible crops, and/or used their extracts (Claudius-Cole *et al*., 2010). All microelements were in the optimal ranges of the healthy orange leaf according to Wutscher and Smith (1994), who noted that adequate ranges for citrus leaf as ppm are 35 - 135 (Fe), 19 - 50 (Zn), 19 - 100 (Mn), 5 - 15 (Cu). Here from Table 1, it can be noticed that soil texture is sandy, it's known that coarse textured soil lacks both nutrient and water holding capacities. Also, under high soil pH value, availability of some nutrients is expected to be low, EC and most elements were in the medium level, and soil organic matter is used as an indicator of soil fertility. Also, this difference in the uptake of nutrients may be attributed to variation in the breakdown of some elements with time which may alter metal availability for crops (Alloway and Jackson, 1991).

All treatments were significantly equal in its fruit weight and the canopy of trees. Radiation is the most important limitation to the performance of the crops particularly when the shade tree forms a continuous shading canopy (Miah *et al*., 1995). Whilst reduction in temperature around rape plants under moringa can also be considered as a possible explanation for reduced rape yield by unpruned moringa, shading gave yield increment when compared with unshaded production due to the increase of the average single fruit weight (Rylski and Spigelman, 1986). In addition, Krizek *et al*. (2006) show that tomato fruits from plants grown under selective ultraviolet film type had more weight compared to fruits grown under commercial field. Such, increase in tree canopy is important because the largest trees usually use the most water and result in highest fruit yield (Syvertsen and Smith, 1996). These results are in agreement with those reported by (Abd El-Naby and El-Sonbaty (2016); Abd El-Naby (2004).

Both shading treatments did not affect the quality of orange fruits. Dayioglu and Hepaksoy (2016) observed that using shade net gave no negative impact on fruit quality and maturation. Ilic and Fallik (2017) found that netting have been shown to influence the retention of sensory qualities at harvest, as that there were no significant differences in total soluble solids in fruits harvested under different colored shade nets.

Conclusions

It can be recommended that, to reduce the problem of low productivity of Washington navel orange trees could be overcome by the use of shade trellis structure to give it the largest number of fruits, which led to the largest yield as distributed more efficiency of the trees, followed by the cultivation of moringa seedlings among the rows of orange trees, which had no adverse impacts on the trees.

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