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Effect of Foliar Application of Different Potassium Forms and Concentrations on Leaves Nutrient Content, Fruit Yield and Quality of Fremont Mandarin

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ABSTRACT
This experiment was carried out during two successive seasons of 2020 and 2021 on 6 years old Fremont mandarin variety grown in sandy soil under drip irrigation system, in a privet farm located at Regwa district, Cairo / Alexandria Road, Beheira Governorate, Egypt, to elucidate the effect of foliar spray of different potassium forms; K_2SO_4; KNO_3 and KCl, sprayed at three concentrations, i.e., 0.0%, 0.5% and 1%, three times a year (at the end of July, August, and September) on fruit yield and quality, and leaf minerals content. The obtained results indicated that all potassium forms at different concentrations and time of application had a positive effect on fruit yield, fruit physical and chemical characteristics, and leaf minerals content, in comparison with control treatment (T1). KCl at 0.5% (T4) was the best treatment regarding increasing fruit yield parameters (as number of fruits /trees, yield as Kg /tree and tons /hectare). In addition, spraying K_2SO_4 at 0.5% (T2) and 1.0 % (T3) were found to be the most superior treatment in enhancing and improving fruit physical and chemical properties. Moreover, KNO_3, spraying at 0.5% (T4) and 1% (T5) were more successful treatments in improving leave mineral status. Finally, it could be concluded that foliar spraying of different potassium forms be an efficient method for improving the most studied fruit yield and mineral nutrients parameters of Fremont mandarin.
Keywords: Fremont mandarin, potassium, foliar spray, chemical composition, yield parameters.

1. Introduction

"Fremont" is a type of mandarin orange that is widely grown in Egypt and other parts of the world. Due to the elevated cost of plantation and production, recently, growers focused on increasing yields per acreage unit rather than having new plantations (USDA, FAS, 2023). During the past couple of years Egyptian growers' preference to cultivate Fremont mandarin over other mandarin types due to the increasing demand for Egyptian Fremont in international markets and joint government and private sector successful efforts in opening new markets. In recent years, the agricultural development program in Egypt aims to increase the areas cultivated with mandarin varieties, especially Fermont, in newly reclaimed lands (El-Khayat and Aseel, 2020). Planted areas of mandarins reached about 108,134 acre (acre = 0.42 ha), represented about 22.5% of total area of citrus, and produce 977,885 ton represented about 22.6% of the total citrus production (4,323,030 tons) according to Anonymous (2019).

As maximizing agricultural productivity has become an imperative necessity to meet the steady increase in population growth worldwide, crop fertilization is becoming more intensive and specialized, and the use of potash fertilizers produced from different potassium raw materials is growing. The quality of the fruit depends on proper nutrient supply and may deteriorate under improper nutritional supplies (Rather *et al.,* 2019). Mineral nutrition of citrus trees is one of the most important inputs for enhancing growth, reproductive behavior and to ensure high productivity with a good quality of fruits (Iglesias *et al.,* 2007). Citrus trees need potassium in large quantities, as one of the essential elements.

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for citrus nutrition (Alva *et al.,* 2001). It is involved in numerous chemical and physiological processes vital to plant growth, yield, and quality (Marschner, 2011). Since, potassium is an important element for increasing yield and improves fruit size, color, and flavor of mandarin trees (Ashraf *et al.,* 2010). Applying fertilizer to the foliage of growing plants, with suitable element concentrations are named foliar feeding. It is a relatively new and controversial technique (Bernal *et al.,* 2007 and Baloch *et al.,* 2008). Foliar application of potassium is a recent technology in horticultural crops. In this regard, several researchers suggested that potassium foliar feeding is considered as a good direct way to the metabolite sites a substitute or supplement potassium addition to soil application, and enhanced fruit yield and quality attributes (Calvert & Smith, 1972; Erner *et al.,* 1993; Mostafa & Saleh, 2006; Yadav *et al.,* 2014). Moreover, it has also been observed that leaves absorbed potassium within 10-24 hours after spray (Alshaal and El-Ramady, 2017). Recently, nutrients foliar application has gained importance in rectifying the deficiencies of potassium element, due to that sometimes soil application is not effective because some parts of potassium leach down in the soil. Foliar application of potassium among other nutrients plays a regulatory role in physiological processes of plants and the availability of nutrients is easy and quick to absorb by the plants. In addition, foliar fertilization is more economical than roots one due to the higher efficiency and lower cost. In this respect, Quaggio *et al.* (2011) evaluated the effect of two K-forms (K_2SO_4 and KCl) at 0, 100, 200 and 300 kg/ha on yield and fruit quality of Pear and Valencia oranges. They found that fruits yield increased with increasing K doses, while total soluble solids decreased. Also, Hamza *et al.* (2015) evaluated two K-sources with different concentrations (KNO_3 at 0, 5% and 8% and K_2SO_4 at 2.5% and 4%) to verify their effect on Cadoux Clementine fruit characteristics. They noticed that foliar application of different potassium forms in different concentrations increased fruit weight, fruit size, color, firmness, and rind thickness, while slight increases in acidity percentage and total soluble solids were observed. One of the mechanisms for improving plant tolerance to stresses is to apply potassium, which seems to have beneficial effects mitigate the adverse effects of stresses by increasing translocation and maintaining water balance within plants (Wang *et al.*, 2013). Furthermore, under abiotic stress conditions such as salinity, drought and heat stress, potassium may contribute to reduce excess absorption of sodium and chloride by citrus trees (Hasanuzzaman *et al.,* 2018).

Based on the abovementioned, the aim of this paper is to study the effect of foliar sprays of different potassium forms; potassium sulphate, potassium chloride and potassium nitrate at different concentrations (0, 0.5%, and 1%) on nutritional status, yield and fruit quality of Fremont mandarin trees cultivated on sandy reclaimed soil in Egypt.

2. Materials and Methods

This study was conducted at a privet farm located at Regwa region, Wadi El-Faregh (Western Desert of Nile Delta), Beheira Governorate, Egypt. Trials were carried out during the two successive seasons (2020 and 2021) on 6-years old Fermont mandarin trees grafted onto *Volcmariana* rootstock and planted at 3x6 meters apart grown on sandy soil using drip an irrigation system. Data in Table (1) show the physical and chemical properties of the experimental soil, which determined according to the procedures outlined by Wilde *et al.* (1985). The selected trees were uniform in vigor as possible as it can. The mineral fertilizers, at the recommended rates for citrus trees, were used as mentioned in control treatment (T1). Soil applications of 190 Kg-N, 72 Kg-P_2O_5, 160 Kg-K_2O and 60 Kg-CaO per hectare were spilted during vegetating and fruit growth stages, using ammonium sulphate, ammonium nitrate and calcium nitrate as sources of nitrogen, phosphoric acid as a source of phosphorus, potassium sulphate (SOP) as a source of potassium and calcium nitrate as a source of calcium. Other agricultural practices were the same for all treatments.

The following seven treatments were investigated and arranged in a Randomized Complete Block Design (RCBD) with three replicates, each replicate consists of one tree: -

T_1- Control (mineral fertilizers, at the recommended rates and sprayed with water only.
T_2- (T_1) + Foliar spray with (K_2SO_4), at 0.5% concentration.
T_3- (T_1) + Foliar spray with (K_2SO_4), at 1 % concentration.
T_4- (T_1) + Foliar spray with KNO_3, at 0.5 % concentration.
T_5- (T_1) + Foliar spray with KNO_3, at 1 % concentration.

T_6- (T_1) + Foliar spray with KCl, at 0.5 % concentration.
T_7- (T_1) + Foliar spray with KCl, at 1 % concentration.

The three potassium forms were assigned to the main plot, while the three concentrations of each K-forms were assigned to the sub-plot. Each treatment was replicated three times. This makes 27 experimental units. All foliar spray treatments were applied three times every season; at the end of July, August, and September.
The following parameters were measured for each experimental unit, in the two years of the study:

2.1. Yield of fruits per tree (Count): At harvest time, the numbers of fruits per tree were counted.

2.2. Yield as Kilograms per tree: yield as Kg /tree was estimated by multiplying number of fruits per tree by mean average fruit weight **(gm).**

2.3. Yield as ton/ha was estimated by multiplying the yield per tree by numbers of trees per hectare.

2.4. Fruit Physical and chemical characteristics: Sample of 10 fruits from each replicate were used to measure mean of fruit weight (gm.), mean of fruit length (L) as (cm), mean of fruit width (W) as (cm), and fruit shape index (L/w).

2.5. Fruit Chemical characteristics: Juice acidity percentage (TA %) was determined by titrating 5 ml of juice against 0.1 N sodium hydroxide using phenolphthalein as an indicator and calculated as citric acid percentage using the method outlined by A.O.A.C. (2000). Total soluble solid (TSS %) was determined by handy refractometer and then, TSS/Acid ratio was calculated.

2.6. Leaf mineral content: For chemical analysis, full expanded mature leaves of 4-6 months old were collected from non–fruiting shoots in early November of each year of the study. Each sample consisted of 30 leaves/tree. Leaves were washed several times with tap water, rinsed with distilled water and then dried at 70°C until a constant weight, ground and digested according to Chapman and Pratt (1975). Nitrogen, phosphorus, potassium, and magnesium as well as micronutrients were determined using the method outlined by Wilde *et al.* (1985).

2.7. Statistical analysis: Data was analyzed with the analysis of variance (ANOVA) procedure of MSTATC program. Treatments were compared by Duncan's multiple range tests at 5% level of probability (Steel and Torrie, 1980).

3. Results and Discussion

3.1. Soil characterization and nutritional status

As shown from results presented in Table (1), the soil of the experimental field is non saline, where the values of electrical conductivity (EC_e) were 478 mg Kg^1 and 369 mg Kg^1 in the tested two soil layers: 0-30 cm and 30-60 cm, respectively. Under such EC_e conditions, it has no negative apparent effects on nutrients availability in the soil (Szabolics, 1971). The data in the same Table show that soil reactions measured as soil pH (1:2.5) were relatively alkaline tendency and reached to 7.88 and 8.04 for the two soil layers (0-30 cm and 60-90 cm), respectively. In this context, Dhingra *et al.* (1965), stated that soil with a pH ranging from 8.1 to 8.5 and an electrical conductivity of 0.4 dS/m in the soil root zone is suitable for good growth and productivity of citrus, and any values higher than that may lead to chlorosis of the leaves. According to Soltanpour *et al.* (1979) and Havlin and Soltanpour, (1981), experimental soil content from P, Mn, Zn, Cu and Fe ranging between low to high concentration, as shown in Table (1). However, under such high pH values, the availability of some essential nutrients such as P, Mn, Zn, Cu and Fe is decreased (Lucas and Davis, 1961).

Data in the same Table shows that nitrogen (N) concentrations in the two soil layers; (0-60 cm & 60-90 cm) were low, ranging from 120 to 140 ppm. This might be due to the rapid change's status caused under the Egyptian soil and environmental conditions. Considering the available soil-K contents of the experimental field, data presented in Table (1) revealed that available soil-K, in the surface and sub surface soil layers were 48 ppm and 40 ppm, respectively, which are far from the adequate level (150 ppm), but rather still below the low level (100 ppm). In addition, in sandy soils, it is expected that potassium will be subjected to leaching losses (McNeal *et al.,* 1995). Under such unfavorable soil conditions, the production of citrus crops will be uneconomic, unless farmers must apply high rates of chemical potassium fertilizers through soil and/or foliar spray to maintain satisfactory yield and quality.

Table 1: Physical and chemicals characteristics of the experimental soil.

Parameter	Soil Depth (0-30 cm)	Soil Depth (30-60 cm)
pH (1:2.5)	7.88	8.04
TDS, mg kg 1	478	369
N-Total, mg kg 1	120 **(L)**	130 **(L)**
P, mg kg 1	30 (M)	35 (H)
K, mg kg 1	48 **(L)**	40 **(L)**
Fe, mg kg 1	2.05 **(L)**	1.84 **(L)**
Cu, mg kg 1	0.03 **(L)**	0.18 **(L)**
Mn, mg kg 1	3.07 (H)	3.52 (H)
Zn, mg kg 1	1.77 M	1.95 (H)

According to Hornek *et al.* (2011): L=Low, M=Medium, H=High

3.2. Number of fruits, yield per tree, and yield per hectare

Results regarding the effect of foliar spray of different potassium forms; K_2SO_4; KNO_3 and KCl, sprayed at different concentration, i.e. 0.0%, 0.5% and 1% are given in Table (2). Data revealed that potassium supplementation as foliar spray showed a positively significant effect on Fruit number/tree, yield per tree (Kg/ tree) and yield per hectare (ton/ ha) compared to control treatment (only water spray) in both 2020 and 2021 seasons.

Table 2: Effect of foliar spraying with different potassium forms on number of Fruits tree-[1], Fruits Yield (Kg tree^{-1}) and yield (tons/ha) of Fermont mandarin during 2020 and 2021 seasons.

Treatments	Mean number of (Fruits tree 1)		Mean Yield, (Kg tree 1)		Mean Yield, (Tons hectare 1)	
	2020	2021	2020	2021	2020	2021
T1: Control	623.3^{d}	626.0e	68.7^{c}	72.3^{b}	33.8^{c}	35.4^{b}
T2: K_2SO_4 (0.5%)	750.0^{b}	760.0^{bc}	87.7^{ab}	88.3^{a}	42.8^{ab}	43.6^{a}
T3: K_2SO_4 (1.0%)	676.7^{c}	715.0^{d}	91.3^{a}	95.0^{a}	45.3^{a}	46.9^{a}
T4: KNO_3 (0.5%)	746.7^{b}	745.0^{Cd}	90.0^{a}	91.7^{a}	45.3^{a}	45.3^{a}
T5: KNO_3 (1.0%)	773.3^{b}	789.0^{b}	95.3^{a}	96.3^{a}	47.0^{a}	47.8^{a}
T6: KCl (0.5%)	856.7^{a}	860.0^{a}	99.9^{a}	97.7^{a}	49.4^{a}	48.6^{a}
T7: KCl (1.0%)	621.7^{d}	610.0^{e}	75.7^{bc}	73.3^{b}	37.1^{cb}	36.2^{a}

Means with the same letters in the same column are not significantly different at $p \leq 0.05$.

The highest values in this respect were recorded when trees were sprayed with 0.5% KCl and reached (856.70 and 860.00 fruit/tree), (99.90 and 97.70 Kg/tree) and (49.40 and 48.60 ton/ha) during 2020 and 2021 seasons, respectively. Spaying trees with KCl at 1% concentration recorded the lowest number of fruits per tree (612.7 and 610.0 fruit/tree) in first and second season, respectively, and followed with control treatment (623.3 and 626.0 fruit/tree), in both seasons of the study. The data obtained showed that spraying Fermont mandarin with KCl at a concentration of 0.5% gave the highest fruit yield as Kg/ tree (99.9 Kg and 97.7 Kg) in 2020 and 2021 seasons, respectively. Spraying trees with only water (Control treatment: T1) had lowest yield per tree (68.7 Kg and 72.3 Kg/tree), in both years of the study, respectively. All other treatments increased fruit yield per tree over control and spraying with KCl (1%) treatments, however, differences were not significant at level of 5% probability. All forms of potassium spraying caused significant increments in Fruit yield (Kg tree^{1})

and total yield (tons hectare [1]) as compared with control. In addition, other treatments were intermediate in this respect.

3.3. Fruit physical characteristics

3.3.1. Effect of treatments on fruit weight (g), fruit length (cm), fruit width (cm) and fruit shape index (L/W) of Fermont mandarin.

The effect of foliar spray of different potassium forms; K_2SO_4; KNO_3 and KCl, sprayed at different concentration, i.e. 0.0%, 0.5% and 1% on fruit physical characteristics (Fruit weight (g), fruit length (cm), fruit width (cm) and fruit shape index (L/W) of Fermont mandarin are given in Table (3). It was found that spraying Fremont mandarin trees with higher concentration of K_2SO_4; at 1.0 % (T3) recorded the highest significant values of fruit weight (135.70 gm and 132.30 gm), fruit length (6.23 cm and 6.00 cm), fruit width (6.43cm and 6.57 cm), in both seasons respectively. However, there were significant differences among values of fruit shape index due to spraying any of tested potassium forms or concentrations in both 2020 and 2021 seasons. On the contrary, when trees were sprayed with only water (control treatment (T1), they gave the lowest values in this respect (110 gm and 115 gm), (5.17 gm and 5.27 cm) and (5.03 cm and 5.07 cm) for fruit weight, fruit length and fruit width in 2020 and 2021 seasons, respectively. In addition, other treatments were intermediate in this respect. This trend was truthful in the two seasons of the study.

Table 3: Effect of foliar spraying with different potassium forms on Fruit weight (g), fruit length (cm), fruit width (cm) and fruit shape index (L/W) of Fermont mandarin during 2020 and 2021 seasons.

Treatments	Fruit weight (g)		Fruit length (cm)		Fruit width (cm)		Fruit shape index (l/w)	
	2020	2021	2020	2021	2020	2021	2020	2021
T1: Control	110.0[b]	115.7[b]	5.17[d]	5.27[c]	5.03[c]	5.07[d]	1.03[a]	1.00[a]
T2: K_2SO_4 (0.5%)	116.7[b]	116.3[b]	5.55[c]	5.53[bc]	5.70[b]	5.63[c]	0.97[a]	1.00[a]
T3: K_2SO_4 (1.0%)	135.7[a]	132.3[a]	6.23[a]	6.00[a]	6.43[a]	6.57[a]	0.93[a]	0.90[a]
T4: KNO_3 (0.5%)	120.0[ab]	122.7[ab]	6.03[ab]	5.87[ab]	6.33[a]	6.27[ab]	0.93[a]	0.93[a]
T5: KNO_3 (1.0%)	123.3[ab]	122.0[ab]	5.93[ab]	6.00[a]	6.27[a]	6.33[ab]	0.93[a]	0.93[a]
T6: KCl (0.5%)	116.7[b]	113.7[b]	6.00[ab]	5.67A[bc]	6.23[a]	6.13[b]	0.93[a]	0.93[a]
T7: KCl (1.0%)	122.3[ab]	120.0[ab]	5.87[Bc]	5.87[ab]	6.27[a]	6.40[ab]	0.97[a]	0.90[a]

Means with the same letters in the same column are not significantly different at $p \leq 0.05$.

3.4. Chemical characteristics of Fremont mandarin fruits

3.4.1. Total soluble solids (TSS %)

The results illustrated in Table (4) showed that foliar spraying with different potassium forms; K_2SO_4; KNO_3 and KCl at different concentrations i.e. 0.0%, 0.5% and 1%, significantly increased total soluble solids (%TSS) in both seasons of the study as compared to control treatment. Data shows that foliar spray with K_2SO_4 at 0.5% (T2) was superior in increasing the percentage of TSS and gave the highest recorded values, which reached to 12.70% and 12.60 % during the first and second seasons of the study, respectively. On the other hand, control treatment (T1) recorded the lowest values in this parameter (11.17% and 11.31 %) in the two seasons, respectively. Also, spraying Fermont mandarin with K_2SO_4 1% conc.(T3), KNO_3 0.5%(T4) conc., and KNO_3 1% conc. (T5) caused a remarkable increase in TSS % compared to control treatment (T1); trees sprayed with water only.

3.4.2. Fruit acidity (%):

Data in Table (4) revealed that, fruit acidity of Fermont fruits was greatly affected with different K-forma and concentrations (T2 to T7) and produced less fruit acidity compared with those sprayed only with water (control, T1). The lowest fruit acidity figures were produced from Fermont trees sprayed with K_2SO_4 1% conc.(T3) 0.94% and 0.91% in the first and second season, respectively.

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Whereas, the highest values of fruit acidity were recorded when trees were sprayed with only water (T1) and reached 1.27% in both seasons of the study. Other treatments were intermediate in this respect and the difference between treatments did not reach to the level of significance 5% probability.

3.4.3. Fruit TSS/acid ratio:

The TSS/Acid ratio as the sugar/acid ratio is the key characteristic that determines the flavor, texture and feel of fruit segments. It is also an indicator of commercial and sensory maturity. Data in Table (4) revealed that fruit TSS/acid ratio of Fremont trees fruits sprayed with the higher dose of 1% K_2SO_4 (T3) produced fruits having the higher ratio between TSS and acidity (13.00 and 13.33) followed by KCl treatment at 1%. (T7) (12.00 and 12.00 in both seasons. Meanwhile, the lowest ratio between TSS and acidity was obtained from Fremont fruits of trees sprayed only with water (control- T1) (8.67 and 9.00 %), in the two years of study. Other treatments were in between range in this respect and the difference between treatments did not reach to the level of significance at 5% probability.

Table 4: Effect of foliar spraying with different potassium forms on TSS %, Acidity % and TSS/Acid ratio of Fermont mandarin fruits during 2020 and 2021 seasons.

Treatments	TSS (%)		Acidit y (%)		TSS/ac id ratio	
	2020	2021	2020	2021	2020	2021
T1: Control	11.17^{d}	11.31^{d}	1.27^{a}	1.27^{a}	8.67^{b}	9.00^{b}
T2: K_2SO_4 (0.5%)	12.70^{a}	12.60^{a}	1.13^{ab}	1.16^{ab}	11.67^{a}	11.33^{ab}
T3: K_2SO_4 (1.0%)	12.37^{ab}	12.33^{ab}	0.94^{b}	0.91^{b}	13.00^{a}	13.33^{a}
T4: KNO_3 (0.5%)	12.07^{bc}	12.07^{bc}	1.32^{ab}	1.20^{ab}	10.67^{ab}	10.67^{ab}
T5: KNO_3 (1.0%)	11.47^{c}	11.30^{d}	1.06^{ab}	1.09^{ab}	10.67^{ab}	10.33^{ab}
T6: KCl (0.5%)	11.70^{cd}	11.80^{cd}	0.98^{b}	0.97^{ab}	12.00^{a}	12.00^{ab}
T7: KCl (1.0%)	11.93^{bc}	11.97^{bc}	0.97^{b}	0.96^{ab}	12.33^{a}	12.33^{a}

Means with the same letters in the same column are not significantly different at $p \leq 0.05$.

3.5. Leaf minerals content

3.5.1 Macronutrients

Data in Tables (5 and 6) indicated that foliar application of different potassium forms; K_2SO_4; KNO_3 and KCl at different concentrations i.e. 0.0%, 0.5 % and 1% caused a remarkable improvement in leaf content from both macro and micronutrients in the two years of the study (2020 and 2021). Nitrogen, phosphorous and potassium in leave of Fremont mandarin were significantly improved due spraying trees with different potassium forms as compared to control treatment (Table 5). The highest percentage of nitrogen, phosphorous and potassium content in leave were recorded in T5 when trees were sprayed with KNO_3 (1.0%) and reached to (2.47% and 2.63 %), (0.23% and 0.30 %) and (1.72% and 1.81%) for nitrogen, phosphorous and potassium content in the first and second seasons, respectively. Meanwhile, the lowest percentage of nitrogen, phosphorous and potassium content in leave were found in T1: control treatment (2.21% and 2.06 %), (0.17% and 0.15%) and (1.46% and 1.51 %) during both seasons of study, respectively. Other treatments were in between range in this respect. As for the percentages of calcium and magnesium content in leave of Fremont mandarin tree results in Table (5) cleared that, Ca and Mg percentages were obviously improved due to spraying the trees with different potassium sources and doses. T4: trees sprayed with KNO_3 at 0.5% conc. and (T5): KNO_3 at 1.0% conc. recorded the highest values (3.28% and 3.42%) and (0.43% and 0.45%) in the first and second seasons, respectively. On the contrary control, treatment (T1) scored the lowest figures in this respect (2.90% and 2.77 %) and (0.30% and 0.24 %) for Ca and Mg measured as percentages in both seasons of the study, respectively. On the other hand, other treatments were intermediate in this respect.

Table 5: Effect of foliar spraying with different potassium forms on macronutrients contents in leaves of Fermont mandarin during 2020 and 2021 seasons.

Treatments	N %		P %		K %		Ca %		Mg %	
	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
T1: Control	2.21[b]	2.06[f]	0.17[d]	0.15[d]	1.46[e]	1.51[d]	2.90[d]	2.77[e]	0.30[f]	0.24[e]
T2: K_2SO_4 (0.5%)	2.18[b]	2.30[cd]	0.21[bc]	0.19[c]	1.52[d]	1.53[d]	3.07[c]	3.11[d]	0.33[e]	0.33[d]
T3: K_2SO_4 (1.0%)	2.31[ab]	2.34[c]	0.20[c]	0.21[c]	1.55[C]	1.57[c]	3.21[ab]	3.25[b]	0.35[d]	0.35[cd]
T4: KNO_3 (0.5%)	2.36[ab]	2.40[b]	0.22[ab]	0.26[b]	1.61[b]	1.65[b]	3.28[a]	3.42[a]	0.41[b]	0.41[b]
T5: KNO_3 (1.0%)	2.47[a]	2.63[a]	0.23[a]	0.30[a]	1.72[a]	1.81[a]	3.21[ab]	3.25[b]	0.43[a]	0.45[a]
T6: KCl (0.5%)	2.27[ab]	2.25[e]	0.19[c]	0.20[c]	1.61[b]	1.63[b]	3.16[b]	3.19[c]	0.38[c]	0.37[c]
T7: KCl (1.0%)	2.23[ab]	2.27[de]	0.20[c]	0.18[c]	1.56[c]	1.56[c]	3.14[bc]	3.16[cd]	0.37[c]	0.35[cd]

Means with the same letters in the same column are not significantly different at $p \leq 0.05$

3.5.2. Micronutrients

3.5.2.1. Iron (Fe)

Results in Table (6) show that, Fe concentration measured as ppm was greatly affected by foliar spraying of K_2SO_4, KNO_3 and KCl 0.5% and 1% concentrations. The highest Fe concentrations in Fremont mandarin leave were recorded when trees were sprayed with KNO_3 0.5% (T4) and reached to 132.67 ppm and 126.33 ppm followed by KNO_3 1.0% (T5) and reached 129.00 and 122.33 ppm, in both seasons (2020 and 2021), respectively. Meanwhile, the lowest figures in this respect were found under control treatment (T1); reached to111.33 and 110.00 ppm. Meanwhile other treatments are in between range in this respect.

Table 6: Effect of foliar spraying with different potassium forms on micronutrients contents of Fermont leaves during 2021 and 2022 seasons.

Treatments	Fe (ppm)		Zn (ppm)		Mn (ppm)	
	2020	2021	2020	2021	2020	2021
T1: Control	111.33[c]	110.00[f]	22.33[e]	29.67[d]	40.00[d]	45.00[e]
T2: K_2SO_4 (0.5%)	114.00[c]	113.67[e]	30.33[c]	34.00[bc]	46.00[c]	56.67[a]
T3: K_2SO_4 (1.0%)	123.00[b]	117.67[cd]	32.33[bc]	34.33[b]	48.33[c]	49.00[cd]
T4: KNO_3 (0.5%)	132.67[a]	126.33[a]	33.67[b]	38.00[a]	52.33[a]	56.00[a]
T5: KNO_3 (1.0%)	129.00[a]	122.33[b]	37.67[a]	34.00[bc]	52.00[ab]	52.67[b]
T6: KCl (0.5%)	122.23[b]	116.67[d]	31.33[bc]	34.00[bc]	48.33[c]	47.33[d]
T7: KCl (1.0%)	121.67[b]	119.67[c]	27.33[d]	31.33[cd]	49.00[cb]	49.67[c]

Means with the same letters in the same column are not significantly different at $p \leq 0.05$.

3.5.2.2. Zinc (Zn)

Concerning Zn content in Fremont mandarin leaves, Data in the same Table (6) showed that, Zn concentration; measure as ppm was also affected by foliar spraying with K_2SO_4, KNO_3 and KCl 0.5 and 1% concentrations. Spraying KNO_3 1.0% (T5) recorded the highest Zn content in Fremont mandarin leaves in the first season (33.67 ppm) meanwhile, in the second one spraying KNO_3 0.5% (T4) recorded the highest zinc content in Fermont leaves (38.00 ppm). On the contrary control treatment (T1) scored the lowest concentrations to reach (22.23 ppm and 29.67 ppm) during both seasons of the study.

3.5.2.3. Manganese (Mn)

As for the concentrations of Mn in leaves of Fremont mandarin; measured as ppm, all treatments caused a remarkable increment in Mn-content (ppm) in leaves of Fremont trees. In the first season, spraying KNO_3 0.5% (T4) gave the highest concentration of Mn in Fremont mandarin (52.33 ppm), while in the second season K_2SO_4 0.5% (T2) recorded the highest Mn content (56.67 ppm) followed by KNO_3 0.5% (T4) (56.00 ppm). Meanwhile, control treatment (T1) recorded the lowest figures in this respect (40.00 ppm and 45.00 ppm) in the first and second seasons, respectively. Other treatments were in between range in this respect.

4. Discussion

In general, citrus crops consume large amounts of potassium, and the amount of potassium they remove is much higher than nitrogen; 270 kg of nitrogen is required to produce 30 tons of fruit/ha compared to 350 kg of potassium (Bhargva and Singh, 1993). Foliar application of potassium is an ideal potassium fertilization technique to improve the productivity and quality of many crops, such as tomato (Tandon and Sekhon, 1988; Oded and Ozi, 2003; Bidari and Hepsor, 2011). In mangoes, Abdel Razek *et al.* (2013) and Abdel Majeed (2005) found that foliar spray of potassium element improved the productivity of mango trees in terms of number of fruits per plant or fruit yield/plant, and such increments were due to that potassium has a positive effect on fruit set, fruit retention, fruit firmness, and on improving the nutritional status of trees. Such findings were confirmed by the results obtained in earlier works done by Ostois *et al.* (1993), Abdul Majeed *et al.* (2000), and Saleh *et al.* (2001). In orange, fruits yields were positively affected with potassium foliar fertilization. These results are consistent with Shen *et al.* (2016) and El-Mahdy *et al.* (2019) for orange. Also, in this regard, Mostafa and Saleh, (2006) & Aly *et al.* (2011) found that spraying Balady mandarin trees with different K- forms improved fruit weight and increased yield. The importance of potassium (K) in plant nutrition and agricultural crop production has been well documented (Tandon and Sekhon, 1988), and K-foliar spray is being considered as an ideal technique for potassium application to improve tomato production (Oded and Uzi, 2003, Bidari and Hebsur, 2011). Foliar nutrition is ideally designed to provide many elements in conditions that may be limiting production at a time when nutrient uptake from the soil is inefficient or nonexistent (Hiller, 1995).

The results obtained in this study indicated that all potassium forms; K_2SO_4; KNO_3 and KCl and all tested concentrations, i.e. 0.5% and 1% (T2:T7) caused a remarkable significant increase in number of fruits /trees, fruit yield per tree (Kg/tree) and fruit yield (t/ha) compared to T1: control treatment (spraying trees with only water). The increments caused in the fruit yield and quality might be due to the beneficial effect of improving the physiological performance of trees as a result to the improvement caused in essential macro and micronutrients and in particular potassium (Tables 5 & 6). It is well known that potassium positively influences fruit yield in general and fruit quality in particular and the influence of potassium is more than by any other nutrients (Subramanian and lengar, 1978). Furthermore, the results obtained in this study are in harmony with these of Oosthuyes *et al.* (1993), who found that productivity of several mango cultivars was improved by potassium sprays. Moreover, Ebeed & Abd El-Migeed, (2005) and Abd El-Razek *et al.* (2013) observed that yield of mango; estimated as number of fruits/tree or as Kg / tree were increased to reach maximum when trees were sprayed with potassium, and attribute that to beneficial effect of potassium on increasing fruit set, fruit retention and decreasing fruit drop and improving nutritional status of trees. Such findings are confirmed by the obtained results in some other works done by Oosthuyes *et al.* (1993); Abd El–Migeed *et al.* (2000) and Saleh *et al.* (2001). They observed that, yield of mangoes and oranges were enhanced due to potassium fertilization. Such observation is consistent with results obtained by Shen *et al.* (2016) and El Mahdi *et al.* (2019) on pear and orange. Additionally, Vijay *et al.* (2016) reported that spraying different concentrations of potassium nitrate and sulfate on sweet Jaffa orange variety had a positive effect on fruit weight and increasing yield, especially when orange trees were sprayed with 4% potassium nitrate. Also, in citrus crops, and especially, Balady mandarins, Mostafa and Saleh (2006); Ashraf *et al.* (2010) and Aly *et al.* (2011) found that foliar spraying with some potassium forms improve fruit weight (gm) and then led to an increase in the fruit yield (ton/ acre).

In this study, significant positive effects due to foliar spraying with different potassium forms and concentrations on fruit physical characteristics of Fermont mandarin fruits such as: fruit weight (gm), fruit length (L) and width (W) (cm) and fruit shape index (L/W) were noticed as shown from data illustrated in Table (3). The improvement caused in fruit physical characteristics of Fremont mandarin due to potassium fertilization is mainly because the well-known effect of potassium on enhancing the fruit yield and quality, and potassium has a positive effect on fruit set, fruit retention, fruit firmness, and on improving the nutritional status of trees (Tandon and Sekhon, 1988). The results obtained are in accordance with those found by Shaaban *et al.* (2012) and Taha *et al.* (2014). In this respect, Ashraf *et al.* (2010) stated that, fruit size of Kinnow increased with increasing potassium supply. Also, Shen *et al.* (2016) reported that potassium nitrate, phosphate and humate had a positive impact on increasing fruit weight and size. The obtained results in this study are in harmony with the findings of Aly *et al.*, (2011); Sarrwy *et al.* (2012) and El-Salhy *et al.* (2017). The positive effect of potassium on fruits physical characteristics, fruit yield and quality can be explained by that potassium plays an essential and important role in controlling cell water content and carbohydrates biosynthesis and mobilization in plant tissues, consequently carbohydrates play a serious role in vegetative growth, fruit set, yield, and fruit quality Abdel-Nasser, (2010) and Quaggio *et al.* (2011). This could also be due to higher cell division and elongation, and translocation of photosynthesis to the sink on account of K fertilization. These results are in accordance with the findings of Neilsen and Neilsen (2006) and Iglesias *et al.* (2007).

Regarding the effect of different potassium forms and concentrations on improving fruit chemical properties (TSS %, acidity % and TSS/ acid ratio of Fremont mandarin Fruits as shown in Table (4), similar findings regarding increasing in TSS, reducing acidity and higher sugar: acid ratio were also reported by Davarpanah *et al.* (2017) in pomegranate. This may be due to the role of potassium in the synthesis of more carbohydrates and their translocation from leaves to fruits and accumulation of sugars and other soluble solids in fruits and also due to synthesis of more organic acids or by the role of potassium in advancing the maturity by improving the quality parameters at an early stage as quality parameters like TSS, acidity and sugars are influenced by harvesting stages. Similar effects are also reported in sweet orange cv. Jaffa (Dalal *et al.*, 2017) and other crops (Vijay *et al.*, 2016), in mango (Sharma and Sindhu, 2005), in guava (Manivannan *et al.*, 2015), in banana (Yadav *et al.*, 2014) and in apple (Yousuf *et al.*, 2018).

The effect of different potassium forms and concentrations on leaf mineral content of Fremont mandarin, as shown from results illustrated in Tables (5&6), proved that different potassium forms have a pronounced positive effect of leaves macro and micronutrient status. These results agree with those obtained by Aly *et al.* (2011), El Salhy *et al.* (2017) and Reetika *et al.* (2020) on Kinnow and Balady and mandarin. Also, Sarrwy *et al.* (2012) reported that, spraying Balady mandarin trees with potassium nitrate, mono potassium phosphate (MKP) or potassium thiosulfate (KTS); each at 1% and 1.5% concentrations enhanced the concentrations of N, P and K in leaves of Balady mandarin compared to leaves sprayed with only water (control treatment), however, spraying potassium nitrate was superior in this respect as compared with the other potassium forms. Moreover, Abo El-Enien *et al.* (2017) found that, foliar spray of potassium silicate at 2g/l tended to improve leaf N, P and K contents in Valencia orange seedlings. The same improvement in NPK concentration was observed in mango leaves, as mentioned by Ebeed and Abd El-Migeed (2005) and Abd El–Razek *et al.*, (2013). The increments caused in leaf mineral contents due to potassium fertilization may be attributed to improvement of trees biological performance in terms of ability to uptake soil nutrients, and consequently improve nutrients use efficiency (Abdel-Nasser and El-Shazly, 2001). The current results on the effect of different potassium forms and concentrations on the mineral content of Fremont mandarin leaves are consistent with the findings of Obeid and Abdel Majeed (2005) on tomatoes, Abdel Razak *et al.* (2013) on mango (Hendi variety) when sprayed with potassium citrate.

5. Conclusion

Based on the abovementioned results, it could be concluded that foliar spray of different potassium forms; K_2SO_4, KNO_3 and KCl, sprayed at different concentration, i.e. 0.0%, 0.5% and 1%, and sprayed three times during the crop growth period was found to be an effective alternative method to supply Fremont mandarin trees with apart from their requirement from potassium; as a key essential element for improving leaf mineral content and consequently, maximizing physiological and biological performance of Fremont mandarin trees as well, leading to achieving higher yields with bitter quality characteristics. Generally, foliar sprays of potassium in the studied forms could be considered as a fast and effective way to compensate for a part of the Fremont mandarin trees' requirements form this element, especially in the cases that the soil is unable to provide sufficient supply of this element, or any other factors hinder the roots' ability to absorb it.

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