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Effect of Foliar Application of Different Potassium Forms Supported by Zinc on Leaf Mineral Contents, Yield and Fruit Quality of "Balady" Mandrine Trees

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Abstract: This study was carried out during two successive seasons 2010 and 2011 on 13 years old Balady mandarin trees budded on sour orange rootstock and spaced at 4×4 meters apart. Trees were grown in sandy soil at Giza Governorate. Foliar spraying with different potassium forms and as well as potassium nitrate (KNO_3), mono potassium phosphate (MKP) and potassium thiosulfate (KTS) at different concentration supported with chelated zinc at 0.5% for all treatments were applied on the trees either pre or post bloom. The obtained results showed that all potassium forms supported with Zn induced a remarked promotion in leaf mineral status. Also potassium forms enhanced yield and fruit physical and chemical characteristics compared with control trees. The best results with regards to foliar application were obtained by MKP at 1.5% concentration with 0.5% chelated Zn which superior to improve leaves nutritional status. Whereas, enhanced yield and fruit physical and chemical characteristics were obtained by sprayed both KNO_3 and KTS at 1.5% concentrations with 0.5% chelated zinc.

Key words: Balady mandarin · Potassium · Leaf content · Yield · Fruit quality

INTRODUCTION

Citrus occupies a prominent position in the fruit industry of the world, as well as in Egypt. Egypt has a great potential for citrus production when its ecological and other characteristics were considered. It is the most important fruit in Egypt as far as its acreage, production and Exportation potentials are concerned [1]. According to 2007 static's of Agricultural Production, Egypt citrus production is 3.181.000 tonnes coming from 2,109,000 tonnes of orange, 732,000 tonnes mandarins, 297, 000 tonnes lemon and 43,000 tonnes grapefruit, Besides that, there are about 42.000 ha are in the beginning of production. However, about 30% of citrus orchards in Egypt became located on poor soils and newly reclaimed areas. Poor soil fertility and poor fertilization strategies are largely a result of insufficient information on the soil fertility and plant nutritional status of crops in these areas [2]. Productivity of citrus trees depends on many biotic factors as well as climate, site, soil, nutrition and irrigation management [3, 4]. One of the major deficiencies in most of the sandy citrus soils of Egypt is an acute shortage of organic matter and is commonly low in both macro and micronutrients, which can limit tree function. In addition micronutrients deficiency occurs in trees growing in such alkaline soils [5, 6].

Balady mandarin is extensively grown in sandy soils which their inherited fertility is low and pH values in the range of 8.0 to 9.0 and proper nutrients management is required to grow mandarin successfully on such soils [2]. They also concluded that nutrient concentration in Balady mandarin leaves is greatly affected by soil characteristics as well as farm management, thus soil and plant analysis. Adequate supply of plant nutrients is a very important factor to produce the good quality fruits [7-9]. Potassium (K) is highly mobile in plants at all levels, from individual cell to xylem and phloem transport. Potassium also is considered as a key element in fruit production and quality worldwide. On the other hand, Potassium plays a critical role in citrus trees and it affects many phenomena both visible and invisible. Since, Potassium plays a regulatory role in physiological and

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bio-chemical processes of citrus plant [10]. Potassium (K) has been ignored for long time in fertilization of most crops in Egyptian agriculture. However the importance of (K) was felt after construction of "high Dam", which prevented the deposition of Nile Silt that enriched with the minerals bearing K such as hydrous mica and feldspars [11], also after beginning cultivate a new reclaimed area. K was the only element which exhibited a low or deficient in different Egyptian soils [12]. Potassium fertilization was reported to increase fruit production up to leaf K contents in Florida, Brazil and Australia [13-15].

The most common methods of applying potassium to citrus are the traditional broadcasting of granular materials or by injection of liquid nutrient solutions through the irrigation system. Nutritional potassium sprays are usually not a substitute to ground applications supplemental nutrient sprays have been shown to be effective in correcting potassium deficiencies for citrus [16, 17]. El-darier [12] suggested that correcting K problem in Balady mandarin by soil application of either K_2SO_4 or KNO_3 or sprays of both. The selection of the appropriate method depends in large extent on the $CaCO_3$ content of the soil. He also reported that soil application of K failed to raise leaf K content but sprays increased it. Foliar-applied potassium nitrate has been found by many recent studies as a potent tool to increase yields, specific fruit components and individual fruit size of various citrus species [16, 18]. Calvert [19] also reported that foliar sprays of potassium nitrate were more effective in rapidly increasing the potassium content of leaves than ground applied fertilizers. Foliar K sprays can be an effective method to shorten the time required for uptake compared to soil application [20]. Mostafa and Saleh [21] reported that spraying potassium nitrate with girdling had a positive effect on leaf mineral content, fruit set and yield as number or fruits weight of citrus. Also such treatments enhanced fruit volume, soluble solids content and SSC/acid ratio. On the other hand, the same treatments reduced acidity and vitamin C in juice of the fruit. In addition, spraying potassium using different forms had a positive effect on leaf mineral content, fruit set and yield as number or fruits weight of citrus trees [22, 23]. Also, Boman [24] reported that foliar treatments with both MKP and KNO_3 were effective in increasing fruit.

Zinc (Zn) is one of the micronutrient required of normal plant growth. The role of Zn in plant is due to its requirement in the synthesis of tryptophan which is a precursor of IAA and the formation of this growth substance is directly influenced by Zn. Zinc deficiency is widespread in citrus trees in Egypt [25]. Marschner [26] mentioned that in soils with very high pH and very low in organic matter, availability of Zn to plant roots is extremely low. In addition, Boaretto *et al.* [27] and Sanchez and Righetti [28] found that when severe Zn deficiency symptoms appear, early spring foliar sprays could increase the micronutrient concentration in the targeted organs. Also, it could stimulate vegetative growth [29, 30]. Application of $ZnSO_4$ (0.5%) significantly increased final yield through increasing fruit set, efficiency of fruiting and decreasing June drop and pre-harvest drop. Also, this treatment improved physical and chemical fruit properties as well as leaf content of Zn and Mn [31, 32].

The aim of this study was to investigate the effect of foliar spray with different potassium forms as well as potassium nitrate, mono potassium phosphate and potassium thiosulfate at different concentration on yield, fruit quality and leaf nitrogen, phosphorus and potassium content of "Baldy" mandarin trees.

MATERIALS AND METHODS

The present study was carried out during two successive seasons 2010 and 2011 on 13 years old Balady mandarin trees budded on sour orange rootstock and spaced at 4×4 meters apart. Trees were grown in sandy soil at Giza, Governorate, Egypt. The experiment was arranged in a complete randomized block design with three replicates, each replicate considered one tree. The experiment involved the following seven treatments:

- Control (water spray trees).
- Foliar spray with potassium nitrate (KNO_3) at 1% + chelated zinc at 0.5%.
- Foliar spray with potassium nitrate (KNO_3) at 1.5% + chelated zinc at 0.5%.
- Foliar spray with mono potassium phosphate (MKP) at 1% + chelated zinc at 0.5%.
- Foliar spray with mono potassium phosphate (MKP) at 1.5% + chelated zinc at 0.5%.
- Foliar spray with potassium thiosulfate (KTS) at 1% + chelated zinc at 0.5%.
- Foliar spray mono potassium thiosulfate at (KTS) 1.5% + chelated zinc at 0.5%.

All treatments were spraying twice (late May and late July).

Leaf Mineral Content: In late July of each season leaf samples were taken randomly from non-fruiting and non-flashing terminal shoots, washed with tap water then with distilled water, dried at 70°C until constant weight, ground and finally digested by using method of Piper [33]. The digested solution was used to determine N, P and K percentage in leaves, which estimated by standard procedure according to Chapman and Pratt [34].

Yield and Fruit Physical and Chemical Characteristics: At harvest time (last week of December), the yield expressed in weight (kg) and number of fruits per tree was recorded. Ten fruits were randomly collected from all sides of the trees under treatments and both physical characteristics [fruit weight (gm), fruit volume (cm^3), specific gravity (gm/cm^3), fruit length (cm), fruit diameter (cm) and fruit shape index] and chemical characteristics [TSS (%), Acidity (%), TSS/Acidity ratio and Vitamin C (%)] were determined by the methods described by AOAC [35].

Statistical Analysis: The obtained data were statistically tested for analysis of variance using MSTAT-C [36] and the significant differences among the various treatments were compared using L.S.D values at provability of 0.05 according to Walter and Duncan [37].

RESULTS AND DISSCUSION

Leaf Minerals Contents: Fig. 1 indicated the effect of spraying different forms of potassium with 0.5% chelated Zn on leaves N, P and K contents of Balady mandarin trees during the two successive seasons of this study.

Concerning potassium contents in the leaves, results showed no significant effects between all potassium forms and concentrations in the first season, but all treatments recorded a significant difference against control treatment (1.50%). The highest value of leaves potassium content was recorded with KNO_3 sprayed at 1.50% (1.73%). On the other hand, all treatments showed significant differences in the second season. The highest significant value was obtained by KTS sprayed at 1.50% (1.77%) with no significant differences by KTS sprayed at 1% (1.70%) and MKP sprayed at 1 and 1.5% (1.6 and 1.68 for the two treatments, respectively). The obtained results are in agreement with those reported by Mostafa and Saleh [21] and Mostafa *et al.* [23] on Balady mandarin, since spraying potassium from several forms i.e. KH_2PO_4 or K_2HPO_4 or KNO_3 raised N, P and K levels in the leaves. Also, Calvert [16], Boman [24] and El-darier [12] suggested that spraying either K_2SO_4 or KNO_3 is more effective than soil application to correct K problem in Balady mandarin.

Number of Fruits and Yield per Tree: All sprayed treatments increased both Number of fruits and yield per tree compared with the control treatment (Fig. 2). Regarding to number of fruits, it was cleared that the foliar sprays with KNO_3 at 1.5% with 0.5% chelated Zn recorded the highest number of fruits (436 and 441fruits/tree in both seasons, respectively) compared with other treatments. Control treatment recorded the lowest number of fruits per tree (377 and 482 fruits/tree in the first and second seasons, respectively). The obtained data showed that spraying Balady mandarin with KNO_3 at 1.5% raised the yield per tree significantly in both seasons compared with other treatments (60.6 and 64.19 Kg/tree in the two seasons, respectively), while trees sprayed with KTS at 1.5% had the highest yield per tree in the first season only (61.25 Kg/tree) with no significant difference compared with tree treated by MPK at 1.5%. On the other hand, the lowest yield of fruits per tree was obtained by control treatment (43.99 and 46.47 in both seasons, respectively).

The presented data are in agree with those obtained by Achilea *et al.* [18] and Erner *et al.* [19] who reported that foliar-applied potassium nitrate was a potent tool to increase yields of various citrus species. Also, Mostafa and Saleh [21] reported that spraying potassium nitrate with girdling had a positive effect on fruit set and yield as number or fruits weight of citrus. In addition, Mostafa *et al.* [23] and El-Fangary [22] found spraying potassium using different forms had a positive effect yield as number or fruits weight of citrus trees.

Fruit Physical Characteristics: The effect of different potassium forms and concentration on fruit physical characteristics [fruit length (cm), fruit diameter (cm), fruit shape, fruit weight (g), fruit volume (cm^3) and fruit specific gravity (g/cm^3)] of Balady mandarin trees was presented in (Fig. 3).

Data of fruit length revealed that all treatments had a significant differences compared with control treatment. Foliar spraying with KNO_3 at 1.5% with 0.5% chelated Zn recorded the tallest fruits (6.43 and 6.6 cm in the first and second seasons, respectively), while the shortest fruits were obtained by control trees (5.50 and 5.30 cm in the two seasons, respectively). On the other hand, the highest value of fruit length was obtained in the first

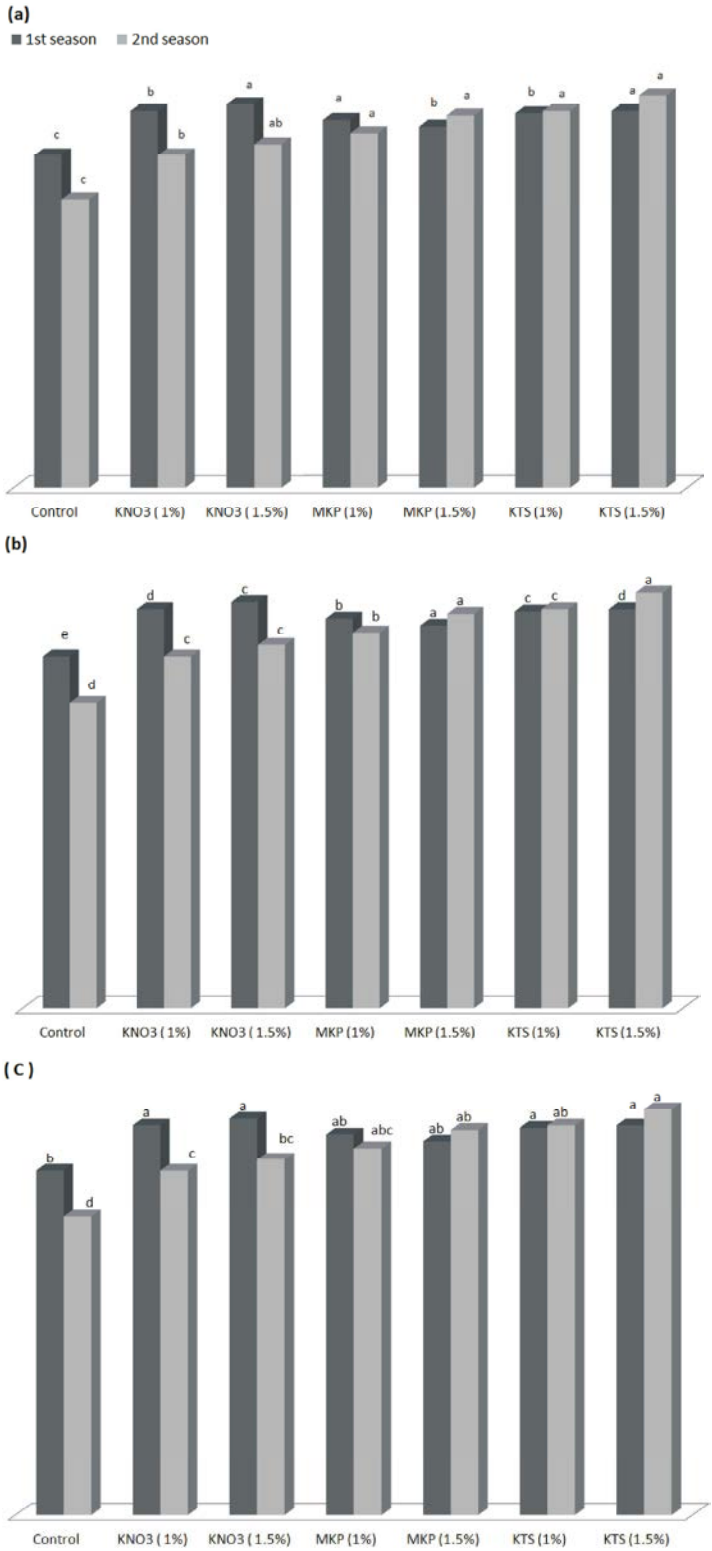

Fig. 1 (a-c): Effect of different potassium forms and concentration supported by zinc on leaf mineral content of cv. Baldy mandarin, (a) % of Nitrogen, (b) % of phosphorus, (c) % of Potassium. Columns with different letters show significant differences at p= 0.05 using LSD

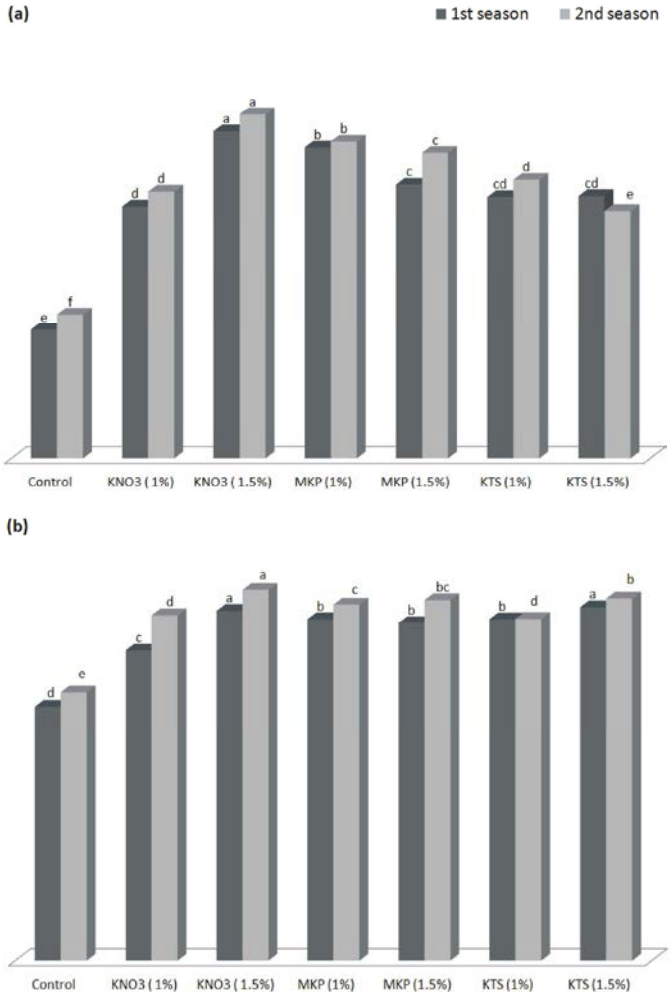

Fig. 2 (a-b): Effect of different potassium forms and concentration supported by zinc on fruit Yield of cv. Baldy mandarin, (a) Average number of fruits/tree, (b) yield (Kg/tree). Columns with different letters show significant differences at p= 0.05 using LSD

season by spraying trees with MKP at 1% with 0.5% chelated Zn (6.60 cm) with no-significant difference compared with KTS at 1.5% with 0.5% chelated Zn (6.57 cm) and KNO_3 at 1.5% with 0.5% chelated Zn (6.43 cm).

Regarding to fruit diameter, data cleared that all potassium forms and concentration were significantly differences compared with control trees. KTS at 1.5% with 0.5% chelated Zn gave the highest significant fruit diameter in both studied seasons compared with all other treatments (7.20 and 7.10 cm in the two seasons, respectively), whereas, the lowest fruit diameter was obtained by control treatment (6.20 and 6.17 cm in the first and second seasons, respectively). Trees sprayed with KNO_3 at 1.5% with 0.5 chelated Zn gave the highest value in the second season only (7.17 cm) with no-significant differences compared with trees sprayed by KTS at 1% with 0.5% chelated Zn (7.13 cm) and KTS at 1.5% with 0.5 chelated Zn (7.10 cm). As fruit shape, all treatments produced fruits tend to oblate shape, but all it was a significant differences between all potassium forms and concentrations in the first season. On the other hand, trees treated with KNO_3 1% with 0.5% chelated Zn produced fruits more tend to spherical shape than other treatments in the two studied seasons (0.94 and 0.97 in the both seasons, respectively), while control trees produced fruits more tend to oblate shape than all potassium forms and concentrations (0.89 and 0.86 in the two studied seasons, respectively).

Concerning fruit weight, all trees treated with different potassium forms and concentrations were significantly differences than control trees. KTS at 1.5%

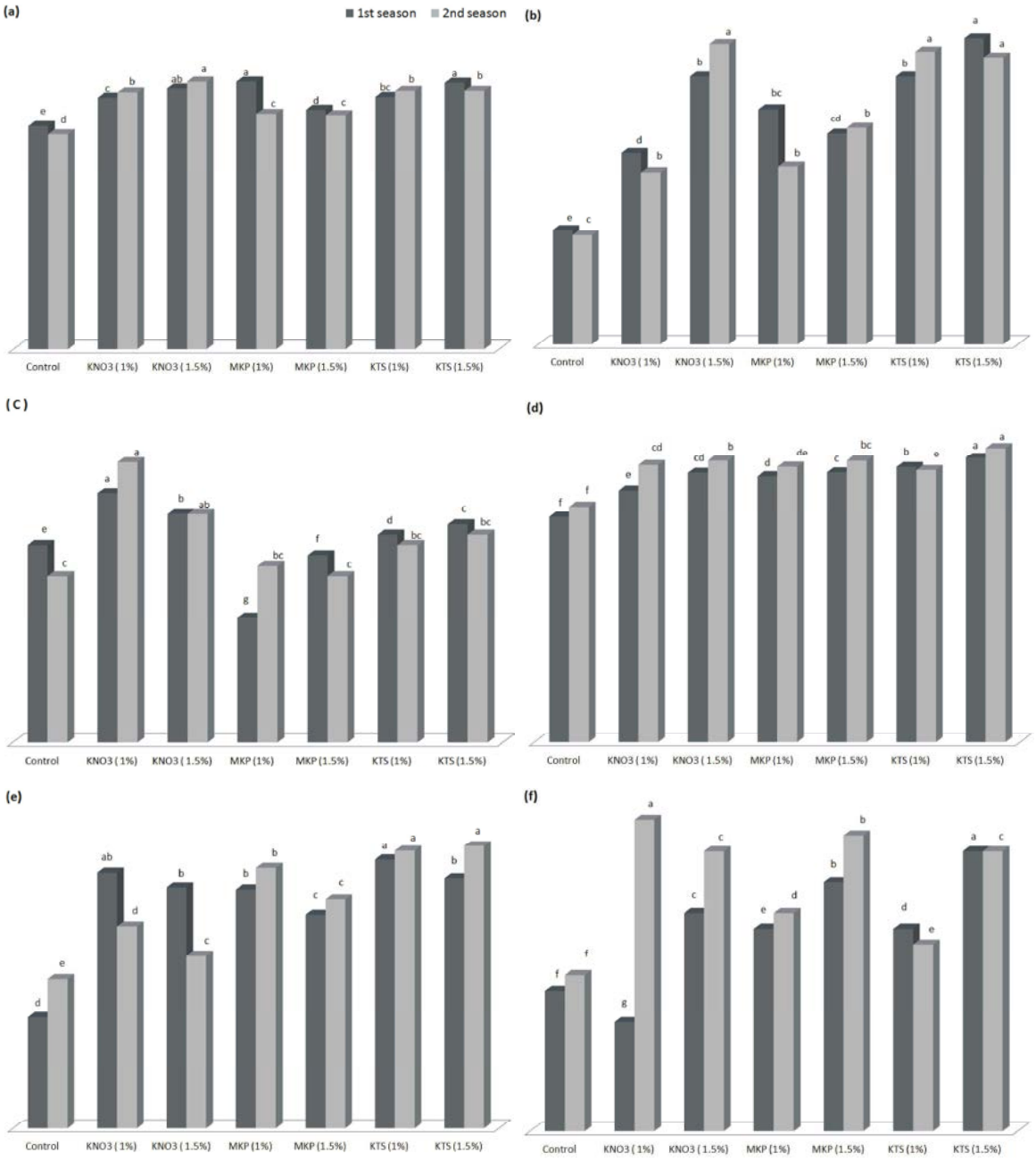

Fig. 3 (a-f): Effect of different potassium forms and concentration supported by zinc on fruit physical characteristics of cv. Baldy mandarin, (a) fruit length (cm), (b) fruit diameter (cm), (c) fruit shape, (d) fruit weight (g), (e) fruit volume (cm^3), (f) fruit specific gravity (g/cm^3). Columns with different letters show significant differences at p= 0.05 using LSD

with 0.5% chelated Zn treatment produced the heaviest fruits compared with other treatments (146.9 and 152 gm in the first and second seasons, respectively). On the contrary, control trees produced the lightest fruits (116.5 and 121.6 gm in the two seasons, respectively). In relation to fruit volume, all treated trees were significantly differences compared with control trees. Trees sprayed with KTS 1% with 0.5% Zn gave the largest fruits than other treatments (159 and 160.3 cm^3 in both seasons respectively), whereas, trees treated with KTS at 1.5% with 0.5% chelated Zn gave the highest value in the second season (161 cm^3) with no significant difference

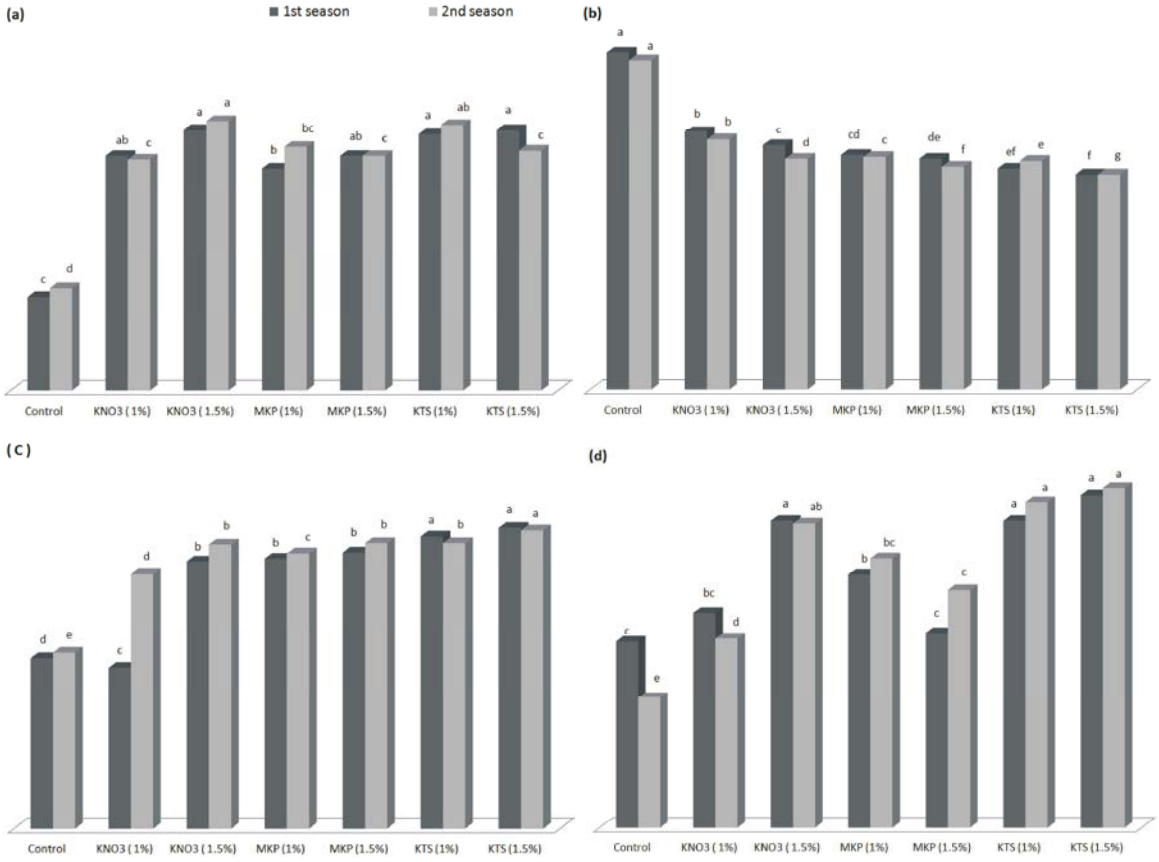

Fig. 4 (a-c): Effect of different potassium forms and concentration supported by zinc on fruit chemical characteristics of cv. Baldy mandarin, (a) TSS (%) (cm), (b) acidity (%), (c) TSS: acidity ratio, (d) vitamin C (%). Columns with different letters show significant differences at p= 0.05 using LSD

compared with KTS at 1% with 0.5% chelated Zn. The lowest size was produced by control trees (136.2 and 141.7 cm3 in the two studied seasons, respectively).

Regarding to specific gravity, all treatments produced significantly more heavy fruits compared with control treatment. No trend showed in the two studied seasons. Since, KTS at 1.5% with 0.5% chelated Zn gave the highest value in the first season (0.94), whereas, KNO_3 at 1% with 0.5% chelated Zn gave the highest value in the second season (0.96). The lowest value was calculated at control trees which recorded 0.85 in the first season and 0.86 in the second one, respectively. Foliar-applied potassium nitrate has been found by many recent studies as a potent tool to increase fruit size of various citrus species [18, 19]. In the same trend, presented data were agreement with those obtained by Mostafa and Saleh [21], El-Fangary [22] and Mostafa *et al.* [23]spraying potassium using different forms had a positive effect on physical characteristics of Balady mandarin.

Fruit Chemical Characteristics: Fig. 4 explained fruit chemical characteristics (T.S.S (%), Acidity (%), TSS/Acidity ratio and vitamin C (%)) of Baldy mandarin fruits sprayed with different forms and concentrations of potassium. All treated trees produced a significant high TSS percentage fruits compared with control trees. Foliar spraying by both KNO_3 at 1.5% with 0.5 chelated Zn and KTS at 1% with 0.5% chelated Zn gave the highest significant percentage of T.S.S in the two studied season (11.53 and 11.60 % for KNO_3 with 0.5% chelated Zn treatment and 11.50 and 11.57 for KTS at 1% with 0.5% chelated Zn treatment in both seasons, respectively). Trees treated with KNO_3 at 1% (11.33%), MPK at 1.5% (11.33%) and KTS at 1.5% (11.53%), with 0.5% chelated Zn had no significant differences compared with those treated with KNO_3 at 1.5% and KTS at 1%, with 0.5% chelated Zn in the first season. The lowest T.S.S percentage observed at control fruits which recorded 10.23 and 10.30% in the two studied seasons, respectively.

Regarding to acidity, all treated trees produced less acidity fruits than control trees. The least acidity fruits was produced from trees sprayed by KTS at 1.5% with 0.5% chelated Zn (1.11 and 1.11% in the first and second seasons, respectively), whereas, the highest value of fruit acidity determined at fruits produced from control trees (1.74 and 1.7% in the two studied seasons, respectively). As TSS/Acidity ratio, both KTS concentrations with 0.5% chelated Zn recorded the highest value of T.S.S/Acidity ratio compared with other treatments. All treated trees had a significant differences compared with control trees. The highest ratio was calculated by treatment of KTS at 1.5% with 0.5% chelated Zn (1.36 and 1.27 in both seasons, respectively), while there was no significant difference compared with KTS at 1% with 0.5% chelated Zn (1.06) in the first season. Control trees recorded the lowest significant T.S.S/Acidity ratio (5.87 and 6.06 in the two studied seasons, respectively). Chelated Zn and KNO_3 at 1.5% with 0.5% chelated Zn recorded the highest significant values of vitamin C percentages compared with other treatments. The highest value was calculated by KTS at 1.5% with 0.5 chelated Zn (34.73 and 34.90 in the first and second seasons, respectively). On the other hand, control trees recorded a significantly lowest value of vitamin C (31.33 and 30.03 in both seasons, respectively). Mostafa and Saleh [21], El-Fangary [22], Mostafa *et al.* [23], El-Deeb [38] and Shawky *et al.* [39] reported that spraying various citrus varieties with different potassium forms enhanced soluble solids content, while, SSC/acid ratio and fruit juice acidity was not or slightly affected. Acidity and ascorbic acid were not significantly affected due to potassium treatments.

CONCULOSION

From the abovementioned results it could be concluded that Balady mandarin trees grown under Egyptian Sandy soil condition greatly respond to foliar application with mono potassium sulphate at 1.5% concentration supported by 0.5 Zn to improve its nutritional status. Whereas, yield and fruit quality of baldy mandarin trees improves by foliar spray with potassium nitrate or potassium thio-sulphate at 1.5% concentration supported with 0.5% Zn.

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