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Research Article
Potassium Forms as a Macronutrient Application to Maximize Fruit and Oil Productivity of *Jatropha curcas* (Part 1: The use of Mono Potassium Phosphate (MKP))

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Abstract

Objectives: This investigation was aimed to study the effect of foliar spraying with mono potassium phosphate (MKP) to maximize fruit and oil productivity and quality of *Jatropha curcas* trees grown under low quality of soil and water (Suez conditions). **Methodology:** *Jatropha curcas* trees received three different concentrations (0.5, 1.0 and 1.5%) of MKP at full bloom (once) and after fruit set (twice). Changes in leaf mineral content, flowering, fruit yield and seed oil content and their chemical characteristics of *Jatropha curcas* trees were determined. **Results:** The obtained results showed that all mono potassium phosphate spraying induced a remarked promotion in leaf mineral status. Also, enhanced yield and seed physical and chemical characteristics compared with control trees. The best results with regards to foliar application were obtained by spraying MKP at 1% once which superior to increase the number of flowers, fruits per inflorescences, fruit yield per tree and seed weight. A higher proportion of oil and less acidity recorded by mono potassium phosphate at 1.0% spraying once. The lowest peroxide value attained by spraying mono potassium phosphate at 0.5% twice. **Conclusion:** Foliar spraying of mono potassium phosphate at 1% once gave the best results in increasing the number of flowers, fruits per inflorescences, seed weight and a higher oil content with less acidity.

Key words: *Jatropha curcas*, foliar spraying, mono potassium phosphate, fruit yield, seeds oil quality

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Agriculture is one of the main corners of the Egyptian economy. Since the cultivable land in Egypt is not more than 10% of the total land while the remaining land is desert[1,2]. We should look for invading desert is a must for an oil seed plants that can grow well in these deserts. *Jatropha curcas* is considered one of the most practical and scientific solutions for desert plantation and as a good feedstock candidate for biodiesel. It can recently planted to produce high economic value trees under low quality of both soil and water[2].

Finding an alternative fuel source for energy production is a major challenge of the 21st century. *Jatropha curcas* L. is a perennial deciduous shrub belonging to the family Euphorbiaceae and it is widely distributed in the tropics and subtropics areas[3,4]. *Jatropha curcas* L., potentially can become one of the world's key energy crops. In addition, *Jatropha* seeds contain 30-40% oil, which is an ideal feedstock for producing biodiesel[5]. With the increasing interest in biofuel, it is now considered as one of the most promising sources of biofuel and has proved to be a viable feedstock because of the 30% oil composition of its nut[6,7]. On the other hand, crop losses resulting from abiotic stresses such as drought or salinity and low soil fertility can reduce crop yield by as much as 50%. So, fertilization using as a soil or foliar application considered as a major limiting factor for tree productivity. So, fertilization using as a soil or foliar application considered as a major limiting factor for tree productivity[8,9].

Basic agronomic properties of *Jatropha* are not thoroughly understood and the environmental effects have not been investigated yet and no much attention has been given to technical issues that are important in optimizing the yield and quality norms of *Jatropha* seed, although Jatropha is considered to be the most suitable feedstock for production of biodiesel[10,11]. In addition, they stated that, *Jatropha curcas* has been widely planted without knowing its standard package of practice for optimizing the yield. Therefore, a standardized agro-technology of *Jatropha* is required.

Potassium is an essential plant nutrient that plays a very important role in plant growth and development. Its role is well documented in photosynthesis, increasing enzyme activity, improving the synthesis of protein, carbohydrates and fats, translocation of photosynthetic, enabling their ability to resist pests and disease. Also, potassium is considered as a major osmotically active action of the plant cell[12,9], where it enhances water uptake and root permeability and acts as a guard cell controller, beside its role in increasing water use efficiency. Moreover, potassium has a great impact on crop quality, including improved oil and protein content of oilseed crops[13]. In addition, phosphorus is an essential and a non-replaceable constituent of several structural components and its deficiency causes metabolic disturbances in the plant[14]. Phosphorus (P) is vital to plant growth and is found in every living plant cell. It is involved in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next. Foliar nutrition is ideally designed to provide many elements to a crop that may be limiting production at a time when nutrient uptake from the soil is inefficient or nonexistent[15,16]. Thus, the advantages of this technique should be explored, such as the smaller fertilizer use (since foliar fertilization consists of supplying small amounts of nutrients directed to the leaves, lower cost, ease of application, good quality of fertilizer used and fertilizer ready soluble in water[17]. So the present study was carried out to investigate the effect of foliar spray of mono potassium phosphate (MKP) to maximize fruit and oil productivity and quality of *Jatropha curcas* trees grown under low quality of soil and water (Suez conditions).

MATERIALS AND METHODS

Plant material: This study was carried out during two successive seasons of 2014 and 2015 in a private orchard of *Jatropha curcas* trees (4 years old) grown under Suez Government conditions, Egypt, to study the effect of foliar sprays of potassium form such as mono potassium phosphate (MKP) at different concentrations and times on leave mineral contents, fruit yield, seed properties, seed oil content and its quality characteristics.

The selected *Jatropha* trees were uniform in vigor and size, planted at 2×4 m apart. All trees received the same horticultural practices in the orchard. The treatments were carried out by spraying the chosen trees with mono potassium phosphate (MKP) at three different concentrations (0.5, 1.0 and 1.5%), while untreated trees (control) were sprayed with only water. Each treatment consists of three replicates and each replicate were two trees. All trees under the study were sprayed two times; first at full bloom (once) and second after fruit set (twice).

Irrigation water: *Jatropha* trees were irrigated by a drip irrigation system. Plot consisted of 14 lateral lines (35 m) and two drippers for each (16 L h^{-1}). Irrigation process was carried out three times per week (32-40 L day^{-1} $tree^{-1}$). Experimental plots were irrigated by secondary treated sewage water from East Suez Plant, which its characterized in pH (7.5), electrical conductivity (4.22 dS m^{-1}) and sodium adsorption ratio (7.67). Fertilizer program was followed as NPK before flowering and after flower setting and phosphoric acid was injected at 1 L weekly.

Soil: It is sandy loam in texture that determined after Gee and Bauder[18]. The main soil properties were measured by Hanna Instruments HI 2550 pH/ORP/EC/TDS/NaCl Benchtop Meter such as pH in 1:2.5 soil to water (8.3) and electrical conductivity 1:1 soil to water 5.87 dS m^{-1}. Soil $CaCO_3$ (14.5) was determined[19] as and organic matter (0.56) was determined according to Rebecca[20]. Soil water constants were measured according to Klute[21]. Where such as saturation (23.0%), field capacity (15.6%), wilting point (6.4) and available water (9.2) on weight basis. Also drainable pores is 32.1% relative to total soil porosity.

The following parameters were measured in both seasons as follows:

- **Leaf mineral contents:** At the end of each growing season during the first week of September, leaf samples were collected, washed and dried at 70°C until constant weight and then grounded for determining the following nutrient elements (Percentage as dry weight), N, P and K were determined[22]
- **Number of inflorescence per shoot:** During the peak flowering period (May-June), the number of inflorescence present in a shoot was counted
- **Number of flowers per inflorescence:** The inflorescences in each individual shoot were tagged just before their emergence and the total number of flowers per inflorescence was counted
- **Number of fruits per inflorescence:** During the peak fruiting period, total number of fruits per inflorescence present on each plant were counted and average fruits per inflorescence was calculated
- **Fruit yield:** At the maturity stage of the two seasons (mid October), fruits of each tree was separately harvested, then weighed and the yield as kilogram per tree was estimated.
- **Seed characteristics:** Fifty seed per each tree were randomly selected for carrying out the seed measurements as follows:
  - **Seed dimensions:** Seed length and diameter (cm)
  - **Seed parameters:** 100 seed weight (g), 100 seed volume (cm^3)

Seed oil content (%): The seeds were ground using mortar and pestle and 20 g of coarse seed powder was taken for oil extraction. Commonly used solvent extraction method in Soxhlet apparatus was applied, using petroleum ether (Boiling point: 40-60°C) as solvent for extraction of the oil method according to De Pena *et al.*[23] and Woodman[24].

Chemical analysis of oil: Determinations for oil acidity, peroxide value and iodine value were carried out using[23] standard analytical methods.

Statistical analysis: All obtained data during both of 2014 and 2015 experimental seasons were subjected to analysis of variances (ANOVA) according to Snedecor and Cochran[25] and regression and simple correlation were estimated by using MSTAT program. Least Significant Difference (LSD) was used to compare between the means of treatments according to Duncan[26] at a probability of 5%.

RESULTS

Leaf mineral contents: Data presented in Fig. 1 illustrated the effect of spraying mono potassium phoshate as mean affected by different spraying of mono potassium phosphate in both seasons of study. Mono potassium phosphate sprays twice at 1.5% gave the highest leaf content of N, since

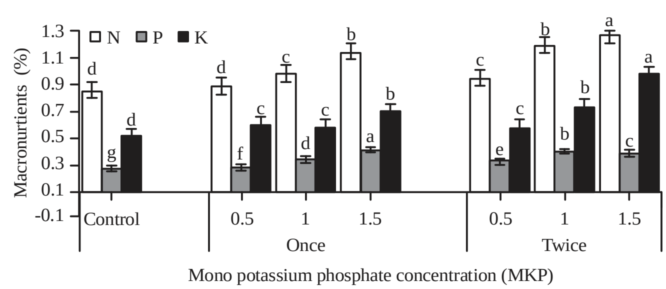

Fig. 1: N, P and K content in leaves of *Jatropha curcas* trees treated with foliar spray of MKP at 0.5, 1 and 1.5% once and/or twice. Values are the means of the two seasons. The vertical bars represent a Mean±SE

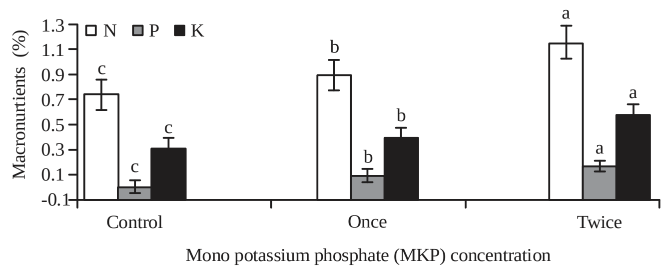

Fig. 2: Effect of number of foliar spraying with (MKP) on N, P and K at the leaf content of *Jatropha curcas* trees treated with foliar spray of MKP at 0.5, 1 and 1.5% once and/or twice. Values are the means of the two seasons. The vertical bars represent a Mean±SE

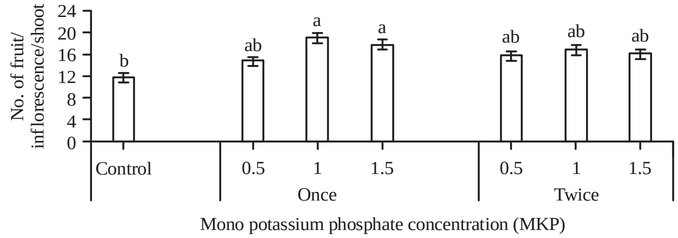

Fig. 3: Number of fruit/inflorescence per shoot of *Jatropha curcas* trees treated with foliar spray of MKP at 0.5, 1 and 1.5% once and/or twice. Values are the means of the two seasons. The vertical bars represent a Mean±SE

it was (1.26) followed by spraying with mono potassium at 1% twice and 1.5% once (1.18 and 1.13), respectively, while control treatment recorded the lowest leaf content of N (0.80). Regarding P content in leaves. Results in Fig. 2 clear that P content in leaves was significantly affected with different spraying treatments. Spraying mono potassium phosphate once at 1.5% recorded the highest value in this respect since it was (0.34) followed by mono potassium phosphate at 1% sprays twice (0.33). On the other contrary, control treatment gave the lowest value in this respect since it was (0.19). Concerning K content in leaves, showed that, spraying mono potassium phosphate led to a significant increase in leaf content of K in both seasons. The highest value of leaves K content was recorded with (MKP) sprayed twice at 1.5% recorded the highest leaves K content followed by (MKP) sprayed at 1% twice and 1.5% once recorded 0.68 and 0.65, respectively. On the other hand, control treatment gave the lowest value in this respect. In general, from these results we can concluded that spraying MKP twice was more effective than once sprays which gave the highest leaves N and K content in both seasons while sprayed (MKP) once recorded the highest one concerning leaves P content.

Macroelement nutrition (NPK): From the experimental study, soil characteristics data, it can notice that the soil is coarse textured, so it suffer from low retain water, the range of the available water is very narrow and the water content at field capacity is moderately but the high content of the salt has a negative effect on, which play an important role in negatively osmotic pressure if leaching requirement take place and daily irrigation is a must to dilute the salt effect on root distribution. Also, the soil contains much salt regarding to the dilution of the soil solution (1:5), so the soil is hard to supply plant either nutrients or irrigation water. Mostly this medium is relatively suitable for hallophite plants such as *Jatropha curcas.*

Flowering properties: Data presented in Fig. 3-5 showed that the effect of foliar sprays of mono potassium phosphate (MKP) on flowering properties as well as a number of inflorescences per shoot, number of flowers per inflorescence and number of fruits per inflorescence. The statistical analysis of data reveals that the number of inflorescences per shoot at flowering stage was significantly influenced by different treatments as compared with control.

The maximum number of inflorescences per shoot (Fig. 4) was recorded under treatment of mono potassium at 1.5 and 1% at once or twice sprays since it was 2.33 and 2.33, respectively. While, the minimum number of inflorescence per shoot was found under control treatment being (1.33). Other treatments were in between ranges. As for numbers of flowers and fruits per inflorescence according to the data illustrated in the same Fig. 5 the total flowers and fruits per inflorescence were highly significantly affected by different application treatments of mono potassium phosphate as compared with

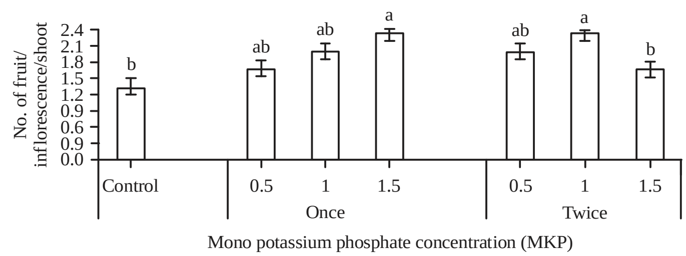

Fig. 4: Number of inflorescence/shoot of *Jatropha curcas* trees treated with foliar spray of MKP at 0.5, 1 and 1.5% once and/or twice. Values are the means of the two seasons. The vertical bars represent a Mean±SE

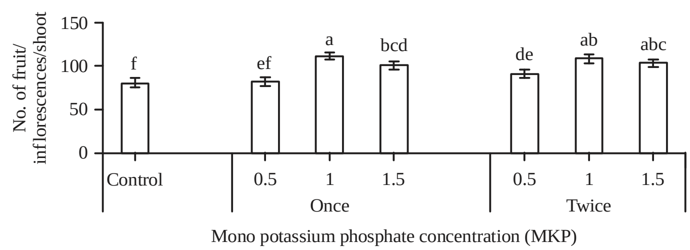

Fig. 5: Number of flowers/inflorescence/shoot of *Jatropha curcas* trees treated with foliar spray of MKP at 0.5, 1 and 1.5% once and/or twice. Values are the means of two seasons. The vertical bars represent a Mean±SE

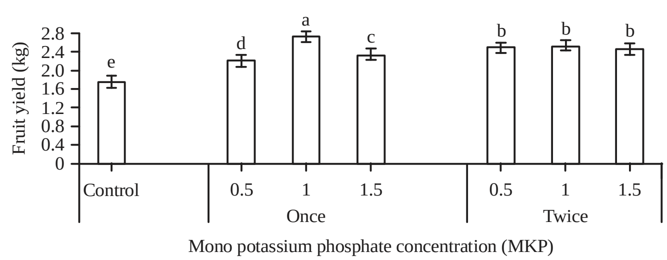

Fig. 6: Fruit yield of *Jatropha curcas* trees treated with foliar sprays of MKP at 0.5, 1 and 1.5% once and/or twice. Values are the means of the two seasons. The vertical bars represent a Mean±SE

control. Foliar sprays of mono potassium phosphate at 1% sprays once recorded the highest value in this respect since it was 111.7 and 19.00 for both numbers of flowers and fruits per inflorescence, respectively. Meanwhile, control treatment being the lowest one in this respect since it was 80.33 and 11.67 for numbers of flowers and fruits per inflorescence, respectively.

Fruit yield: The statistical analysis of data reveals that the fruit yield as weight kilogram per plant at harvest time was significantly affected by different treatments (Fig. 6). The maximum of fruit yield per plant was recorded under treatment with mono potassium phosphate at 1% spraying once being (2943 g), while the minimum of fruit yield per plant was found under control treatment being (1883 g).

Seed physical parameters: Data presented in Fig. 7 and 8 showed that the effect of different spraying mono potassium phosphate on the 100 seed weight (g) and volume (cm^3). Data reveals that the 100 seed weight and volume were significantly affected by different potassium treatments. Spraying mono potassium phosphate at 1 and 0.5% once or twice gave the highest value (46.48 g and 83.33 cm^3) for 100 seed weight and volume, respectively. On the other contrary control treatment recorded the lowest one in this respect since it was (27.00 g and 70.00 cm^3) for 100 seed weight and volume, respectively.

Concerning the seed length and width (cm) data in Fig. 7 cleared that seed length and width were significantly affected by different potassium treatments. Spraying mono potassium phosphate at 0.5 and 1.5%, twice or once recorded the highest value in this respect 2.16 and 2.15 cm for seed

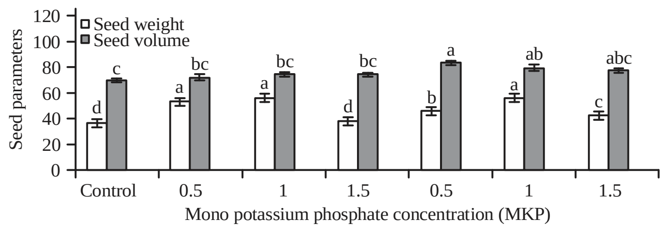

Fig. 7: Seed parameters (weight and volume) of *Jatropha curcas* trees treated with foliar spray of MKP at 0.5, 1 and 1.5% once and/or twice. Values are the means of two seasons. The vertical bars represent a Mean±SE

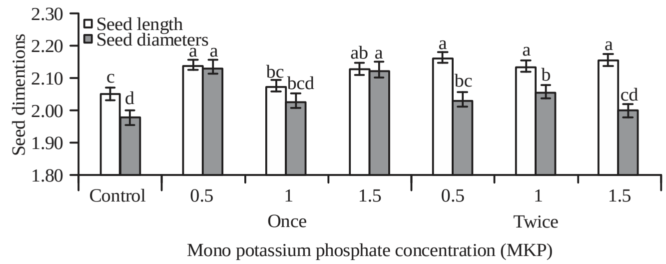

Fig. 8: Seed dimension (Length and diameter) of *Jatropha curcas* trees treated with foliar sprays of MKP at 0.5, 1 and 1.5% once and/or twice. Values are the means of two seasons. The vertical bars represent a Mean±SE

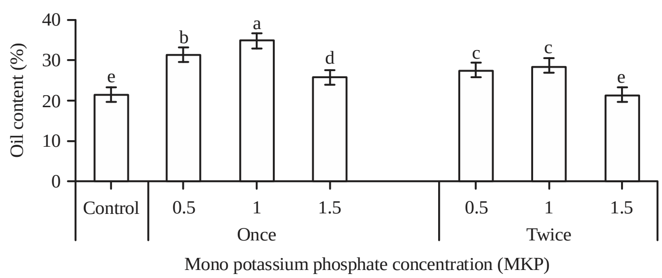

Fig. 9: Seed oil content of *Jatropha curcas* trees treated with foliar spray of MKP at 0.5, 1 and 1.5% once and/or twice. Values are the means of the two seasons. The vertical bars represent a Mean±SE

length and 2.13 and 2.12 cm for seed width, respectively. Meanwhile, control treatment recorded the lowest value since it was 2.05 and 1.98 cm for seed length and seed diameter, respectively.

Seed oil content (%): The percent of *Jatropha* seeds oil (On dry weight bases) by using some different spraying treatments of mono potassium phosphate compared to the control were recorded in Fig. 9. It's clear from the obtained data that all different spraying treatments (sprays once and twice) produced significantly higher seed oil content as compared to the control. Meanwhile, spraying once showed more effect of an increase in the proportion of seed oil compared to spray twice. The highest content of seed oil was attained after treated with 1% mono potassium phosphate sprays once, which had 34.71% followed by 0.5% (31.28%) and 1.5% (25.82%), respectivly. On the contrary, control treatment recorded the lowest content in this respect sicne it was 21.41.

Chemical properties of seed oil: Acidity, peroxide and iodine values of *Jatropha* seed oil under spraying with different contentrtion of mono potassium phosphate compared to the control were illustrated in Fig. 10-12. Oil acid value is used to quantify the amount of acid present and showed a significantly affected by spraying with different contentrtion of mono potassium phosphate (Fig. 10). The highest oil acidity (9.42) recorded by 1.5% spraying once mono potassium phosphate followed by at 0.5% (8.80) while, 1% spraying once recorded the lowest one in this respect (6.61). On the other side, sprays twice gave the best result in reducing oil acidity. Regarding peroxide value which gives the initial evidence of

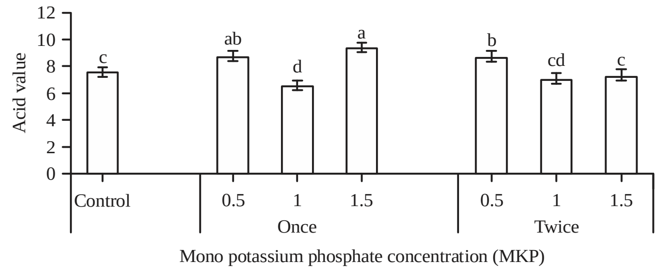

Fig. 10: Oil acid value of *Jatropha curcas* trees treated with foliar spray of MKP at 0.5, 1 and 1.5% once and/or twice. Values are the means of two seasons. The vertical bars represent a Mean±SE

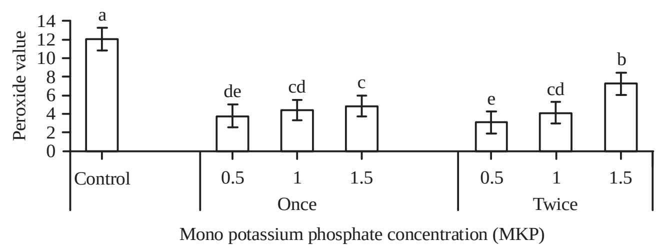

Fig. 11: Oil peroxide value of *Jatropha curcas* trees treated with foliar spray of MKP at 0.5, 1 and 1.5% once and/or twice. Values are the means of the two seasons. The vertical bars represent a Mean±SE

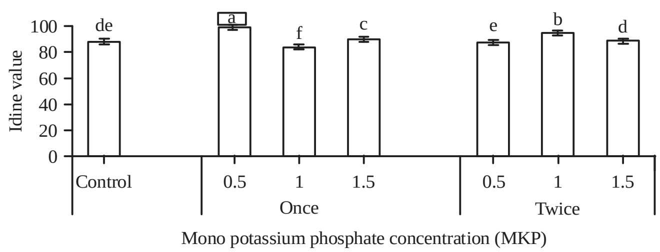

Fig. 12: Oil iodine value of *Jatropha curcas* trees treated with foliar spray of MKP at 0.5, 1 and 1.5% once and/or twice. Values are the means of the two seasons. The vertical bars represent a Mean±SE

rancidity in unsaturated fats and oils was significantly affected by spraying with different contentrtion of mono potassium phosphate recorded in Fig. 11. Spraying mono potassium phosphate at 0.5% twice recorded the lowest peroide value (3.08). On the opposite side, the unreated seedoil gave the highest one in this respect being (12.13).

Concerning iodine value are often used to determine the amount of unsaturation in fatty acids. All trees treated with different contentrtion of mono potassium phosphate were significantly differences than controle trees. Furthermore, spraying mono potassium phosphate at 0.5% once produced the highest iodine value since it was 104.6 followed by 1% twice (99.55). On the other side, spraying mono potassium phosphate at 1% once gave the lowest one in this respect being (88.80) compared to untreated trees (control).

DISCUSSION

The present results, regarding the influence of mono potassium phosphate (MKP) on leaf mineral content are in accordance with those found by Sanna and Abd El-Migeed[27]. As spraying fagri kalan mango trees with potassium citrate improved nitrogen and potassium in leaves. In addition, El-Razek *et al.*[28] and Baiea *et al.*[29] found that spraying mango trees with sward (25% potassium) raised leaf mineral content of N, P and K. Furthermore, Taha *et al.*[30] on mango trees, found that all different potassium forms, applications had a positive effect to improve leave mineral content. Also, Sarrwy *et al.*[31] found that foliar spray of potassium forms on Balady Mandarine raised N, P and K levels in the leaves. Moreover, the improvement in leave mineral content under foliar potassium sprays due to shorten the time required for uptake compared

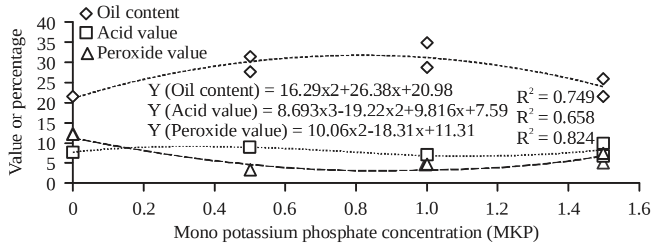

Fig. 13: Relation between mono potassium phosphate concentrations and some oil characters

to soil application[32]. In addition, movement of nutrients within the plant depends largely upon transport through cell membranes, which requires energy to oppose the forces of osmosis. Here again, ATP and other high energy P compounds provide the needed energy.

Concerning flowering and yield, the obtained results are in harmony with these of Montenegro *et al.*[33]. They found that the fertilization of *Jatropha curcas* tree with nitrogen and potassium at a dose of 150+120 kg ha^{-1} increased fruit and seed production by more than 90% as compared with the unfertilized control. The increase in yield may be related to the spray's success in preventing the leaf contents of K and other mineral nutrients from declining to low levels during fruit set[34]. In addition, Mostafa and Saleh[35], El-Fangary[36] and Sarrwy *et al.*[31] found that spraying potassium using different forms had a positive effect yield as a number or fruits weight of citrus trees.

Regarding seed physical and chemical characteristics as well as (seed weight, volume, diameter, oil content and quality), the beneficial effects of potassium on fruit and oil quality may be attributed to their vital role in stimulating cell division and elongation as well as the biosynthesis and enhancing fruiting of trees[37]. Moreover, potassium is an essential plant nutrient that plays a very important role in plant growth and development. Its role is well documented in photosynthesis, increasing enzyme activity, improving the synthesis of protein, carbohydrates and fats. Also, potassium (K) is well recognized as the essential plant nutrient with the strongest influence on many quality parameters of fruits[38,39]. Although, K is not a constituent of any functional molecules or plant structures, it is involved in numerous biochemical and physiological processes vital to plant growth, yield and quality[40]. In addition, to stomatal regulation of transpiration[41]. These results are in agreement with those obtained by Ben Mimoun *et al.*[42] and Sarrwy *et al.*[43] on olive trees reported that potassium fertilization improved yield and quality as well as fruit weight, flesh to pit ratio and oil content of olive fruit.

It is clear that statistical analysis for the obtained data is very important to fulfill the relation between spraying treatments and some oil characters (Fig. 13) could be plotted to describe the vital correletaions. Regression equation obtained were polynomial one, which means that the progressive improve in the previous characters could be happened till specific MKP concentrations then decreased and increased. Data pointed out that the relation between peroxide value as independent variable vs MKP is not clear enough regarding to the obtained equation which is polynomial in the 3rd degree with highly significant R^2, where MKP at 1 g L^{-1} did not fulfill any increase in the studied parameter although 1.5 g L^{-1} get the goal. From the other hand negatively trend was observed or oil content and positively with acid value and R^2 values were 0.749** and 0.658*, respectively. These results could describe on base that increasing MKP associated with increasing oil content till 1.0 g L^{-1} from MKP, while the opposite was true in case of acid value.

The simple correlations were obtained between MKP and leaf content of (N, P, K). The number of inflourescences and number of flowers/iflourescences. The data cleared that the leaf content of N, P and K reflected the close positive highly signioficat (1%) correlation with MKP. Simple correlation with highly significant at 5% between MKP and leaf contenet from N, P and K and number of inflorescence, number of flowers/inflorescence and number of fruits/inflorescence with r values, 0.833**, 0.877**, 0.867**, 0.862**, 0.596* and 0.759**, respectively. Also, MKP had apromotive effect on the values of No. of inflorescence and number of flowers/inflorescence resulted from treated *Jatropha* with mono potassium phosphate (MKP).

CONCLUSION

From the above mentioned results, it can concluded that:

- All foliar application of mono potassium phosphate had a positive effect of increasing leaf mineral content
- Fruit yield, seed physical and chemical properties under examined treatments were improved compared with untreated one of *Jatropha* trees

- The best treatment was spraying mono potassium phosphate at 1% at full bloom (once) that increased the number of flowers, fruits per inflorescence, seed weight and oil content and quality

SIGNIFICANT STATEMENT

- The aim of this study was to increase the productivity fruit and oil productivity and quality of *Jatropha curcas* trees grown under low quality of soil and water (Suez conditions)
- The methodology including the treatments of *Jatropha* trees with three different concentrations (0.5, 1.0 and 1.5%) of MKP at full bloom (once) and after fruit set (twice)
- The obtained results showed that all mono potassium phosphate spraying induced a remarked promotion in leaf mineral status. Also, enhanced yield and seed physical and chemical characteristics compared with control trees
- The best results with regards to foliar application were obtained by spraying MKP at 1% once which superior to increase the number of flowers, fruits per inflorescences, fruit yield per tree and seed weight. A higher proportion of oil and less acidity recorded by mono potassium phosphate at 1.0% spraying once
- Foliar spraying of mono potassium phosphate at 1% once gave the best results in increasing the number of flowers, fruits per inflorescences, seed weight and a higher oil content with less acidity
- The materials used in this study natural and safely for use but the *Jatropha* oil is non-edible oil, only used for biofuel

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