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Nutrient Removal from Different Parts of Koroneiki Olive Trees Grown in Sandy Soil as a Base of Fertilizer Recommendation in Egypt

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Authors' contributions

This study was carried out in collaboration among all the authors. All authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aims: to evaluate nutrient status in Koroneiki olive trees grown in sandy soils and calculate the amount of nutrients annually removed by the olive tree.
Study Design: Costate Statistical package, in order to calculate means, maximum, minimum, standard deviations (SD), with 12 replicates
Place and Duration of Study: El-FIFA farm which is located at km 48 of Cairo-Alexandria road in the north west of Egypt, between January 2011 and December 2012.
Methodology: This experiment was carried out on 10 years-old olive trees cv. Koroneki grown on a loamy sand soil. The trees are cultivated at 6 x 6 meters distance (278 tree/ha^{-1}) and grown using standard cultural practices and subjected to moderate pruning every year. Flesh and pit were separated, weighed and dried. Nutrient concentrations in the flesh and pit were determined and used to quantify the nutrients removed by fruit. The materials removed in pruning were separated to branches and leaves, weighed and dried. Based on the dry matter and nutrient concentration in the different tissues, the amounts of nutrients removed annually in pruning were calculated. Nutrient removals were calculated for every organ, by multiplying dry weight by nutrient concentration. These amounts were added together, to obtain the total nutrient removal/tree.
Results: Leaves have sufficient contents of N, P, K, Ca, Na, Mn, Zn, Cu and B while the level of both Fe and Mg was high. Nutrients removed annually/tree were: 265.24g N;

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37.93g P; 353.93 g K; 122.67 g Ca; 76.94g Mg, 74.78 g Na; 7.288g Fe; 0.773g Mn; 0.514g Zn, 0.213g Cu and 0.663g B., when the yield was77.33Kg/tree.
Conclusion: The results obtained are helpful in calculation fertilizer recommendations.

Keywords: Koroneiki olive; sandy soil; leaf nutrients; nutrients removed; fruit; pruning.

1. INTRODUCTION

The olive industry is one of the most important sectors agriculture in Egypt, which has a great potential for expanding. During the recent years, the agricultural development programs in Egypt aim to increase the cultivated areas around Cairo-Alexandria road in the north west of Egypt. Soils of these areas are characterized by sandy. Olive trees are extensively grown in these sandy soils with pH values in the range of 8.0 to 9.0. Proper nutrients management is required to grow olive successfully on such soils. The area cultivated with olive reached a total of 64927 ha. This includes fruiting area of 52250 ha producing 459650 ton/year (average 8.80 ton/ha).

Olives is grown in old lands in the Delta and valley and in desert reclaimed areas (38005 ha) including 29491 ha producing 236091 ton (average 8.01 ton /ha) [1].

Therefore, about 59% of olive orchards in Egypt are located on poor soils of newly reclaimed areas, which are irrigated. The importance of appropriate fertilization management in irrigated olive orchards was emphasized [2].

The inputs of nutrients from different sources should be equal to the amount removed by the tree. If these amounts are not enough to reach the target yield, the difference should be added as fertilizer. Few researchers [3-13] have studied the nutrient status of olive orchards and nutrient uptake by olive tree.

Information on nutrient removal by olive trees, beside the ability of the soils to retain and supply nutrients is necessary for making fertilizer recommendations. A significant part of the nutrients taken up by olive tree are annually lost by way of fruit harvest and pruning. An assay of the mineral content of the different parts of fruit including pit, flesh and pruned material including wood and leaf can provide quantitative information on the amount of minerals annually removed by these parts away from the soil. Very few or almost no data is available on nutrients removed by olive trees produced in Egypt.

Therefore, it is necessary to have information on nutrients removal for each variety grown in this area. Data on nutrients removed by olive trees under Egyptian condition could not be traced. This information needed to calculate adequate fertilizer requirements for the trees.

Therefore, the objective of this research was to determine the amount of nutrients annually removed by Koroneiki olive tree grown on a sandy soil. This can help to provide a good basis for planning fertilizer program for olive tree orchards.

2. MATERIALS AND METHODS

2.1 Soil Sampling

Soil samples were randomly collected from the zone of the root tips of the trees under the end of canopy in November. Depth of the soil sampling was 0-60cm. Under dry land conditions the installation of a drip system, makes the adult tree adapt its rooting system, concentrating the roots within the wet soil zones near the drippers, so that the highest root densities occur in these zones [14]. The samples were air dried, ground to pass through a 2 mm sieve using a wooden grinding and stored in plastic bottles prior to the physical and chemical analysis. Also, samples of irrigation water were collected during the experiment and analyzed. Total of 8 samples were taken.

2.2 Field Practices

This experiment was carried out on a 10 years- old olive orchard cv. Koroneki at a period between January 2011 and December 2012 on a loamy sand soil at FIFA farm which is located at km48 of Cairo-Alexandria road in the north west of Egypt, where the farm area is about 315 hectares.

The zone is characterized by a semi-arid climate with an annual precipitation of less than 50 mm. The trees were cultivated at 6 x 6 meters distance (278 tree/ha^{-1}) and grown under standard cultural practices, subjected to moderate pruning and irrigated with water having an average of EC 1.53 dS/m and SAR 4.1 Table 1. SAR was expected to be high under the high levels of Na as compared with Ca and Mg. The olive orchard is irrigated with four drippers/tree and irrigation scheme was as following: November, December, January, February: two times/week (550 m^3/ha); March, April, May, June: three times/week (1100 m^3/ha); July, August, September, October: six times/week (2750 m^3/ha). Total= 4400 m^3/ha.

Table 1. Chemical analyses of well's water

Parameter	Value	Parameter	Value
EC dS/m	1.53	Hard soluble Mg	50
SAR	4.1	Mg	12.15
pH	7.26	Na	313
ppm		K	7.52
NO_3	Non	Fe	1.02
PO_4	0.8	Mn	0.24
Cl	147	Zn	0.14
Phenols	Non	Cu	0.07
Ca	123	B	0.05

Trees were uniform in growth. The trees were subjected to the same management treatments. Organic manures were applied as compost at a rate of 40 Kg/tree Table 2.

N, P_2O_5, K_2O rates (288, 74, 192 kg ha^{-1} year) were applied as fertigation, Also, potassium nitrate (KNO_3) was applied three times in January, February and March as foliar spray.

Three foliar sprays of micronutrients were applied during the growing period: before flowering, after fruit set and at the end of the summer.

Table 2. Physical and chemical analysis of compost

Parameters	Value	Parameters	Value
pH	9.01	Total P (%)	0.54
E.C	7.89	Total K (%)	2.64
T.N (%)	1.95	N NH_4 (ppm)	657.9
Organic carbon (%)	28.50	N NO_3 (ppm)	152.9
C/N ratio	14.62		
Organic matter (%)	49.02		

2.3 Leaf Sampling

Leaf samples were collected randomly around the tree from the fully mature leaves on 4-7 month-old young shoots of the spring flush. About 40 fully expanded mature leaves per tree were collected. In all cases, leaves were taken from the middle portion of the current season's terminal shoot growth. Samples were washed with tap water, 0.01 N HCl and distilled water, respectively, then dried at 70ºC and ground in a stainless steel mill, then passed through a 40 mesh nylon sieve and stored in plastic bottles. Total of 16 leaf samples were taken.

2.4 Fruit Sampling

Fruits were separated to flesh and pit and weighed. Material was then dried at 70ºC and used to determine nutrient concentrations; nutrients removed by fruits were then calculated. Total of 28 fruit samples were taken. Yield in year 2011 was 64.66 Kg/tree. Yield in year 2012 was 90 Kg/tree. Average yield in the two years was 77.33 Kg/tree.

2.5 Pruned Material Sampling

The material removed in pruning was separated to branches and leaves and weighed. Material was then dried at 70ºC and used to determine nutrient concentrations. Based on the dry matter and nutrient concentration in the different tissues, the amounts of nutrients removed annually in pruning were calculated. Total of 28 pruned material samples were taken.

2.6 Chemical Analysis

Soil samples were analyzed using the following methods:

- pH and electrical conductivity (EC) using water extract (1:2.5) method;
- Total calcium carbonate ($CaCO_3$%), calcimeter method;
- Organic matter (O.M%) using potassium dichromate [15];
- Phosphorus was extracted using sodium bicarbonate [16];
- Potassium (K), calcium (Ca) and magnesium (Mg) were extracted using ammonium acetate;
- Iron (Fe), Manganese (Mn), Zinc (Zn) and Copper (Cu) were extracted using DPTA [17] and B was extracted using boiling water [18].

Plant samples were analyzed using the following methods:

- The plant material was digested using an acid mixture consisting of nitric, perchloric and sulfuric acids in the ratio of 8:1:1 (v/v), respectively [15];

- Nitrogen (N) was determined in the dry plant material using the boric acid modification and distillation was done using a Buechi 320-N2-distillation unit;
- Phosphorus was photometrically determined using the molybdate vanadate method [19];
- Potassium and calcium was determined using flame photometer Genway;
- Mg, Fe, Mn, Zn and Cu were determined using the Atomic absorption spectrophotometer Perkin Elemer 1100 B and Boron was determined using azomethine-H method [18].

The data were evaluated based on previously reported criteria for the analysis of soil [20,21] and leaf [22-25].

Nutrient removals were calculated for every organ, by multiplying dry weight by nutrient concentration. These amounts were added together, to obtain the total nutrient removal/tree.

2.7 Statistical Analysis

Data were subjected to computer statistical package [26]. Classical descriptors were determined, such as mean, maximum, minimum, standard deviation with 12 replicates.

3. RESULTS AND DISCUSSION

3.1 Soil Properties and Nutrient Status of Soil

The results of soil testing are presented in Table 3. It shows that soil pH is high, EC value is high.$CaCO_3$ is low to medium and organic matter very low. Olive trees grow quite well on soils containing more than 1% of organic matter [27].

Table 3, contains also the average values of the major nutrient concentrations in the soil samples. According to the tentative values of soil characteristics and available nutrient concentrations, K, Ca and Mg concentrations are considered to be low. Also; the levels of Fe, Mn, Zn, Cu and B in the soil are very low, as it's known in most sandy soils.

Table 3. Range, Mean ± SD of physical-chemical characteristics of the soil testing

Character	Min-Max	Mean ± SD	Available nutrient content	Min-Max	Mean ± SD
Sand %	76-81	78.8±2.0	**Macronutrients, (mg/100g)**		
Silt %	6-8	7.3±1.2	P	0.39-0.52	0.43±0.08VL
Clay %	13-15	13.9±1.2	K	7.40-16.82	12.50±4.80L
Texture	**Loamy sand**		Ca	65.6-80.8	74.70±8.10L
pH(1:2.5)	8.76-8.82	8.79±0.03 VH	Mg	9-18	12.70±4.40L
E.C dS/m(1:2.5)	1.05-3.28	1.98±1.16 VH	Na	112-336	208±115H
$CaCO_3$ %	1.60-2.10	1.83±0.25L	**Micronutrients, (mg/Kg)**		
O.M %	0.20-0.27	0.23±0.04VL	Fe	1.60-2.50	2.00±0.50VL
			Mn	2.70-4.80	3.77±1.05VL
			Zn	0.46-0.81	0.61±0.18VL
			Cu	0.26-0.29	0.27±0.02VL
			B	0.71-0.79	0.75±0.04L

VL = very, low L = Low, M = Moderate, H = High, VH= very high

3.2 Nutrient Concentrations in Koroneiki Olive Leave

Data in Table 4 shows the range, mean ± SD of Koroneiki olive leaf nutrient concentrations under this study.

Nitrogen concentrations in the leaves were in the beginning of sufficient range. This may be due to high leaching of ammonium nitrate in such soil with about 79% sand. On the other hand, olive oil quality decreases with over nitrogen fertilization [27].

P-concentrations in the mature leaves were sufficient while, potassium concentrations in the leaves were tended to the sufficient range. Potassium nitrate (KNO_3) was applied three times in January, February and Mars as foliar spray. The best results with regard to foliar application were obtained with KNO_3 at 3% concentration which superior to improve nutritional status, flowering, fruit set, yield and fruit quality of Picual olive trees grown under sandy soil conditions [28].

Calcium concentrations in the leaves were in sufficient range, while magnesium concentrations were in high range. Concerning micro nutrients, it was found that in spite of the low levels of micronutrients in the soil, levels in leaves were not deficient. Fe-concentrations were high. Concentrations of Mn, Zn and Cu were sufficient, while B was > 19 ppm. No correlation was found between available Mn, Fe, Zn and Cu in soil and their content in olive leave [29]. The sufficient levels of micronutrients could be returned to those three foliar sprays of micronutrients which were applied during the growing period.

Table 4.Range, mean ± SD of Koroneiki olive leaf nutrient contents (spring leaves)

Nutrient content	Min-Max	Mean ± SD	Evaluation	Nutrient content	Min-Max	Mean ± SD	Evaluation
Macronutrients, (%)				**Micronutrients, (ppm)**			
N	1.31-1.74	1.55+0.15	Sufficient	Fe	380-550	457.0+59	High
P	0.142-0.185	0.163+0.012	Sufficient	Mn	60-83	71+9	Sufficient
K	1.00-1.30	1.15+0.12	Sufficient	Zn	34-47	41.4+4	Sufficient
Ca	1.60-2.60	2.00+0.30	Sufficient	Cu	5-9	7.3+1.1	Sufficient
Mg	0.318-0.411	0.368+0.036	High	B	16-45	31+14	Sufficient
Na	0.11-0.21	0.19+0.03	Sufficient				

It could be concluded that based on leaf analysis, the orchard did not show deficiency in any of the most vital nutrients.

3.3 Nutrient Concentrations in Fruit and Pruned Material

Contents of N, P, K, Ca, Mg, Fe, Mn, Zn and B for fruit (Flesh& Pit) and pruned material (Branches & leaves) are mentioned in Table 5. In comparison, with different parts, K concentrations were the highest in flesh while Ca concentrations were the highest in branches. Micronutrient concentrations were higher in leaves than fruit and branches, except B was higher in flesh than pit and pruned material.

Table 5. Nutrient concentrations range, mean ± SD of fruits and pruned material of Koroneiki olive

Nutrient	Fruits				Pruned material			
	Flesh		Pit		Branches		leaves	
	Min-Max	Mean±SD	Min-Max	Mean±SD	Min-Max	Mean±SD	Min-Max	Mean±SD
%								
N	0.88-1.05	0.97±0.05	1.13-1.34	1.22±0.06	0.19-0.30	0.23±0.04	1.21-1.61	1.42±0.13
P	0.11-0.17	0.15±0.02	0.08-0.12	0.10±0.01	0.13-0.16	0.14±0.01	0.16-0.18	0.17±0.01
K	1.70-2.20	2.00±0.18	0.20-0.35	0.25±0.04	0.52-0.72	0.61±0.08	1.10-1.50	1.35±0.11
Ca	0.10-0.13	0.11±0.01	0.25-0.56	0.39±0.09	0.75-0.91	0.82±0.03	2.50-3.60	3.17±0.34
Mg	0.13-0.24	0.18±0.04	0.25-0.49	0.34±0.09	0.34-0.51	0.43±0.06	0.32-0.43	0.39±0.03
Na	0.22-0.39	0.31±0.06	0.15-0.25	0.20±0.03	0.21-0.28	0.25±0.02	0.25-0.37	0.29±0.04
ppm								
Fe	160-290	237±48	140-290	210±53	290-420	346±45	410-620	513±71
Mn	10-16	13±2	12-28	18±4	48-97	76±14	80-90	85±3
Zn	9-20	15±3	12-26	17±4	21-38	27±5	31-36	33±1
Cu	5-10	8±2	5-10	7±2	5-11	7±2	7-12	9±2
B	26-36	31±5	7-11	9±2	16-36	26±10	16-26	21±5

Total dry weight in a tree was 28.1 Kg distributed by fruits (80%) and pruned material (20%) Table 6.

Table 6. Fresh and dry weight (mean ± SD) in the fruits and pruned material of / tree

Part	Kg/tree	
	Fresh weight	Dry weight
Fruits	77.33	22.39
Flesh	63.11± 27.11	14.50±6.89
Pit	14.22±6.61	07.89± 2.16
Pruned material	7.21	5.71
Branches	5.41±2.23	4.44±1.83
leaves	1.80± 0.74	1.27± 0.52

3.4 Nutrient Removal of Fruits

Table 7, shows that in fruit material, nutrients removed in flesh represented 59, 73, 94, 33, 49 and 74% respectively for N, P, K, Ca, Mg and Na, and 67, 57, 62 , 68 and 86% respectively for Fe, Mn, Zn, Cu and B, and nutrients removed in pit represented 41, 27, 6, 67, 51 and 26% respectively for N, P, K, Ca, Mg and Na, and 33, 43, 38, 32 and 14% respectively for Fe, Mn, Zn, Cu and B.

3.5 Nutrient Removal of Pruned Material

Nutrients removed in leaves represented 64, 26, 39, 53, 21 and 25% respectively for N, P, K, Ca, Mg and Na and 30, 24, 26, 26 and 19 % respectively for Fe, Mn, Zn , Cu and B and nutrients removed in branches represented 36, 74, 61, 47, 79 and 75 respectively for N, P, K, Ca, Mg and Na and 70, 76, 74, 74 and 81% respectively for Fe, Mn, Zn, Cu and B

Table 7. Average nutrient removal of fruits, pruned material and total nutrient/ year/ per Koroneiki olive tree (g) based on dry weight

Nutrient g/tree	Fruits			Pruned material			Total nutrient/ year/tree
	Flesh	Pit	Total	Branches	leaves	Total	
N	140.7	96.3	237.0	10.21	18.03	28.24	265.24
P	21.61	7.89	29.5	6.26	2.17	8.43	37.93
K	290.0	19.73	309.7	27.08	17.15	44.23	353.93
Ca	15.23	30.77	46.0	36.41	40.26	76.67	122.67
Mg	26.10	26.83	52.9	19.09	4.95	24.04	76.94
Na	44.23	15.78	60.0	11.10	3.68	14.78	74.78
Fe	3.437	1.66	5.10	1.536	0.652	2.188	7.288
Mn	0.186	0.142	0.328	0.337	0.108	0.445	0.773
Zn	0.218	0.134	0.352	0.120	0.042	0.162	0.514
Cu	0.116	0.055	0.171	0.031	0.011	0.042	0.213
B	0.450	0.071	0.521	0.115	0.027	0.142	0.663

It could be concluded that under moderate pruning, fruit and pruned material removed large amounts of nutrients, which make most of nutrients taken up by the tree insufficient for high yield in sandy soils with low cationic exchange capacities. It was found that potassium and nitrogen was the highest nutrients removed. Potassium is the most important macro nutrients removed by the olive-fruit, followed by N, Ca, P and Mg [30].

Nutrient uptake (g/tree/year) in Tunisia was 578 N, 67 P_2O_5, 502 K_2O and in France was 300 N, 60 P_2O_5, 200 K_2O and in Spain was 310 N, 75 P_2O_5, 560 K_2O and in Italy was 276 N, 142 P_2O_5, 488 K_2O [31].In young irrigated olive plants of cv. Coratinain, Lavello (in the south of Italy), Fe, Cu and Zn removed, consisted in few g ha^{-1}[6].

Data of the total unit removed per Koroneiki olive (g/tree/year) are presented in Table 8.

Table 8. Total unit removed per Koroneiki olive (g/tree/year)

Nutrient g/tree	Total nutrient/ year/tree (g)	Factor	Unit	Total unit/ year/tree (g)
N	265.24	-	N	265.24
P	37.93	2.29	P_2O_5	86.86
K	353.93	1.20	K_2O	424.72
Ca	122.67	1.40	CaO	171.74
Mg	76.94	1.66	MgO	127.72

3.6 Calculation of Fertilizers Recommendation

These amounts of nutrients must be returned to the tree with fertilizers, to restore minerals depleted due to removals taking into account the fertilizers efficiency. Fertilizer needs/tree = nutrient needs/tree X nutrient content of the fertilizer X use efficiency of the fertilizer (under the given conditions).

Fertilizer needs/unit area = Fertilizer needs/tree X No. of trees in the area unit.

3.7 Considerations to be Taken when Calculations Fertilizers Needs

Total amount of mineral elements and dry matter were higher in the irrigated olive trees in comparison with the non-irrigated ones [4].

Some nitrogen may be supplied from organic matter in the soil, but this amount is usually small in sandy soils. Nitrogen efficiency under sandy loam soil, high temperature and irrigation is low. About 50% of fertilizer nitrogen losses are resulted from leaching and denitrification of fertilizer nitrates, while ammonium is more protected from leaching.

Soils fertilized regularly with P have an abundant reserve of soil phosphorus. Since phosphorus does not leach, it can build up to high levels in the soil, which can be used by trees in the following years.

Fertilization based on yield removal is better for potassium fertilization than the other nutrients. In sandy soils, potassium is not enough for high-yielding trees. If fruit removal of potassium is greater than fertilizer applied, deficiencies can occur.

Calcium, magnesium and micronutrients must be considered because of their special needs for high fruit quality.

Beside the nutrient removal, soil properties and the behavior of each nutrient in the soil should be considered. Soil testing and plant analysis should be used routinely for a continuous adjustment of the fertilizer program [13].

4. CONCLUSION

It was found under moderate pruning, that fruit and pruned material removed large amounts of nutrients, which can become insufficient for high oil yields in sandy soils. Under the condition of this study, total nutrient removal/ year/ per Koroneiki olive tree (g) was 265.24, 37.93, 353.93, 122.67, 76.94 for N, P, K, Ca and Mg respectively and 7.29, 0.77, 0.51, 0.21, 0.66 for Fe, Mn, Zn, Cu and B respectively.

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COMPETING INTERESTS

Authors have declared that there are no competing interest exits.

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