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Dynamics of macronutrients in olive leaves

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ABSTRACT

The study aims to track the dynamics of the olive leaf nitrogen (N), phosphorus (P) and potassium (K) for five olive varieties under drip irrigation in farmer's fields in central Morocco. Leaf sampling was done every month from May 2014 to April 2015. Leaf macronutrients contents showed variation over time. Olive leaves have maintained the same N content throughout the study period indicating a continuing olive uptake of nitrogen. Higher leaf P absorption was observed during flowering and fruit magnification periods indicating the important P needs of olive during these periods. Olive leaf K levels were higher from September to December indicating the high K needs of olive. No variety effect was revealed on the leaf N, P and K contents. Very highly significant differences were found between the leaf N and K levels measured at different sampling periods. The leaf P concentration was statistically equal in all measuring periods.

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dynamic; leaves; nitrogen; Olea europea; phosphorus; potassium

Introduction

Leaf nutrient analysis is considered the best method for diagnosing the nutritional status of a tree and is an important tool for determining its fertilizer needs (Jones 1985). The tracking of seasonal variations in leaf nutrient contents is necessary in order to understand the physiological aspects of olive nutrition, and is also helpful in the interpretation of leaf analysis (Fernandez-Escobar, Moreno, and Garcia-creus 1999). In the northern hemisphere, flower bud induction is manifested by July, around the time of endocarp sclerification (Fernandez-Escobar et al. 1992). Floral differentiation is manifested by March (Hartmann 1951) and anthesis occurs by May (Alcala and Barranco 1992). Shortly after flowering, massive abscission of flowers and fruits occurs (Rallo and Fernandez-Escobar 1985). The remaining fruits usually persist on the tree until harvest, which takes place during the fall and early winter (Fernandez-Escobar, Moreno, and Garcia-creus 1999). These authors found that leaf age influenced the leaf nutrient content; the leaf nitrogen, phosphorus and potassium contents were higher in young leaves. The differential absorption and translocation of nutrients between different tree species or varieties have been well documented by several authors (White, Chaney, and Decker 1979; Shuxin et al. 2000; Damon and Rengel 2007; Khoshgoftarmanesh et al. 2010). However, for the olive tree which is considered a species with a great capacity to survive and produce in low fertility soils, there is few studies on the dynamics of foliar absorption of nutrients and genotypic differences that may exist among the olive varieties (Chatzistathis and Therios 2009). The change in macro and micronutrient needs along the cropping cycle is important indicator that helps to follow the nutritional demand and to detect any deficiencies or excesses of certain nutrients that can affect both productivity and quality.

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These needs may differ across varieties that could respond differently to a deficiency or toxicity stress (Demiral 2004; Chartzoulakis et al. 2002; Loupassaki et al. 2002; Marschner 1995; Therios and Sakelariadis 1988; Therios and Misopolinos 1988). Paskovic et al. (2013) found differences between the leaf nutrient contents among selected olive varieties. Several studies in Greece and Portugal have shown that the leaf elemental composition, absorption and nutrient utilization capacity, were significantly different for different olive varieties grown under similar ecological conditions, (Dimassi, Therios, and Passalis 1999; Jordao, Marcelo, and Centeno 1999; Toplu, Uygur, and Yildiz 2009). As occur in other fruit trees, the olive yield amount and quality are largely dependent on the ecological environment with optimal inputs management and genetic background of a variety (Michelakis 2002; Bignami et al. 1994; Cimato, Cantini, and Sani 1990).

Thus, understanding the response of olive varieties in different ecological conditions should enhance the development of better fertilization program for a balanced diet and it can also reduce fertilizer costs and environmental hazards by minimizing leaching losses (Bouma 1997). The present work aims to study the dynamics of macronutrients in olive leaves for five olive varieties grown under drip irrigation. The monitoring of the leaf nitrogen (N), phosphorus (P) and potassium (K) levels was performed on olive orchards, at the Sais region in central Morocco, without affecting the farmer's fertility programs that have been established on the basis of soil testing.

Materials and methods

Monitoring the dynamics of nutrients in the olive leaves was carried out in nine olive orchards grown under drip irrigation and owned by three farmers in Sais region (Table 1).

All fertilizer applications made in the three sites are given in Table 2. These fertilization programs differed from one site to another and from one variety to another.

In orchards 1, 2 and 3 (farmer 1), the fertilizers were applied using fertigation method between April and November. In these orchards, the three olive varieties received the same phosphorus and potassium rates, while for nitrogen, the farmer applied different rates; 96, 114 and 167 kg N/ha/year, respectively, for the Arbequina, Koroneiki and Arbosana varieties (Table 2). These monthly fertilizers rates were distributed in several applications (almost daily) covering months of May, June, July, October, the first decade of August and the second half of September. April was characterized by five fertilizer applications that were made toward the end of the month. A foliar spray of potassium (3 kg of potassium sulphate per ha) was applied in September. Farmer 1 provided low phosphorus rate (11.4 kg P_2O_5/ha) for all three varieties if we refer to the soil phosphorus contents in these orchards (Table 5). In orchards 4, 5 and 6 (farmer 2), fertilizers were also applied by fertigation, as before, between April and September (Table 2). Monthly fertilizers rates were generally divided into several applications (twice a week). Foliar sprays based on 20–20–20 at the rate of 2.5 kg/ha, were applied in four applications during the crop cycle (end of March, late April, early June and early September). In orchards 7, 8 and 9 (farmer 3), fertilizers were applied in one application by manual spreading in February (Table 2). A foliar spray containing 2% soluble potassium sulfate was applied in September for the Arbequina and Koroneiki varieties.

Table 1. Characteristics of olive orchards studied.

Farmer	Orchard	Variety	Planting Density	Age (years)
1	1	Koroneiki	1.5*4	9
	2	Arbequina	1.5*4	9
	3	Arbosana	1.5*4	9
2	4	Picual	5*6	8
	5	Arbequina	4*3	10
	6	Moroccan picholine	5*6	7
3	7	Arbequina	3*5	9
	8	Koroneiki	3*5	5
	9	Picual	4*6	4

Table 2. Monthly application of macronutrients in the olive orchards studied.

Site	Farmer 1								
	Arbequina			Koroneiki			Arbosana		
Variety	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Period	Kg/ha								
April	**38.0**	0.3	0.2	**56.0**	0.3	0.2	**112.6**	0.5	0.2
May	16.9	5.7	3.1	16.9	5.7	3.1	16.9	5.7	3.1
June	12.5	4.7	2.6	12.5	4.7	2.6	12.5	4.7	2.6
July	10.3	0.6	0.9	10.3	0.6	0.9	10.3	0.6	0.9
August	3.5			3.7			3.5		
September	**4.1**			**4.1**			**0.8**		
October	9.7			9.7			9.7		
November	0.8			0.8			0.8		
Total/year	**95.9**	**11.4**	**6.9**	**114.0**	**11.4**	**6.9**	**167.1**	**11.5**	**6.9**

Site	Farmer 2								
	Arbequina			Moroccan Picholine			Picual		
Variety	N	P_2O_5	K_2O	**N**	P_2O_5	K_2O	N	P_2O_5	K_2O
Period	Kg/ha								
April	16	20	16	16	20	16	16	20	16
May	24	16	16	24	16	16	24	16	16
June	20	12	20	20	12	20	20	12	20
July	16	4	20	16	4	20	16	4	20
August	20	4	30	20	4	30	20	4	30
September	24	4	30	24	4	30	24	4	30
Total/year	**120**	**60**	**134**	**120**	**60**	**134**	**120**	**60**	**134**

Site	Farmer 3								
	Arbequina			Koroneiki			Picual		
Variety	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Period	Kg/ha								
February	35	75	0	35	75	0	7.8	31.2	7.8
(Total/year)	**35**	**75**	**0**	**35**	**75**	**0**	**7.8**	**31.2**	**7.8**

The bold values represents the difference between the three varieties in terms of N, P and K inputs for the farmer 1.

Ten trees were spotted in each olive orchard studied for sampling the current season's leaves. The leaf samples were taken almost every month totalizing 100 leaves per tree during the period going from May 2014 to April 2015. These leaf samples were subject to laboratory analysis for nitrogen, phosphorus and potassium contents. The leaf nitrogen and phosphorus mineralization was conducted by concentrated sulfuric acid and the leaf potassium mineralization with perchloric acid. Leaf nitrogen, phosphorus and potassium contents were determined by Kjeldahl, colorimetry and photometry, respectively, using the protocol developed by El Gharous, El Amrani, and El Mjahed (1995).

Soil samples were also collected in these olive orchards at two depths (0–30 cm and 30–60 cm). These samples were subject to the following analyzes: pH, particle size distribution by the Robinson pipette method (Day 1965), nitrates by chromotropic acid (Sims et al. 1971), phosphorus by the Olsen method (Olsen et al. 1954), potassium extracted with ammonium acetate (Chapman 1965) and organic matter by Walkley and Black method (Allison 1965). Soil samples were taken in July, October and December to follow the changes in the soil fertility during the olive tree cycle.

The olive harvest was done in December for all the olive orchards.

Table 3. Soil characterization of the studied orchards.

Farmer	Variety	Texture	% Total Limestone	pH		% Organic Matter	
				0–30 cm	30–60 cm	0–30 cm	30–60 cm
1	**Koroneiki**	Heavy clay	34.7	8.0	8.0	1.9	1.1
	Arbequina	Heavy clay	21.4	7.7	8.0	2.1	1.8
	Arbosana	Silty clay	20.9	8.2	7.7	2.5	1.5
2	**Picual**	Heavy clay	3.2	7.7	7.8	1.9	1.4
	Arbequina	Heavy clay	0.5	7.8	7.8	2.1	1.9
	Moroccan picholine	Silty clay	11.7	7.9	7.9	2.9	2.1
3	**Arbequina**	Sandy loam medium	20.6	8.1	8.1	2.2	2.0
	Koroneiki	Clayey sand	34.2	8.2	8.1	1.3	1.3
	Picual	Sandy clay	14.5	8.0	8.2	2.4	1.6

For statistical analysis, we used the linear mixed model with repeated measurements (Littell et al. 2006). Several time-dependent structures have been tried. The structure that made the data better is the compound symmetry. The estimation method is the restricted maximum likelihood. Comparison of the means was performed using the Duncan test.

Particle size analysis of soil samples have shown that these soils are clayey and very clayey in orchards of farmers 1 and 2 and floor sand-dominated textures (clayey–sandy, silty–sandy and sandy) in the orchards of farmer 3 (Table 3). The studied soils are moderately to strongly calcareous for orchards of farmers 1 and 3 and almost non-calcareous for orchards of farmer 2.

Considering the soil clay content, soils studied are ranked as low in organic matter except for orchards 3, 6 and 7 which are moderately rich in organic matter (Table 3).

Soil pH of olive orchards studied ranges from 7.5 to 8.4, defined by Hach company (1992), indicating the presence of free lime in the soil, usually associated with excellent filtration and percolation of water due to high Ca content, associated with low phosphorus availability (Ryan et al. 1996).

Figure 1 shows the monthly precipitation and mean temperatures measured during the study period in Sais region. The rainy period lasted from November 2014 until March 2015 with maximum rainfall (104 mm) recorded in November.

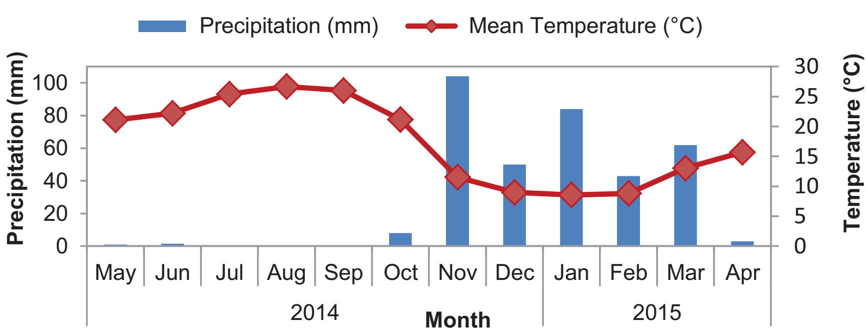

Figure 1. Monthly precipitation and temperatures recorded during the study period in the Sais region.

Results and discussion

Soil fertility

The soil nitrate levels of Arbequina orchard of farmer 1 were highest during the three soil sampling times, in comparison with the other olive varieties of the same farmer (Table 4). For the variety Koroneiki, the soil nitrate content was the lowest during the three soil sampling periods. It is noteworthy to mention that the Koroneiki and Arbequina received, respectively, half and one-third of the nitrogen rate applied to the Arbosana in April for farmer 1 (Table 2). For farmer 2, soil nitrate levels were lowest

Table 4. Soil nitrates variations in the studied orchards.

Farmer	Variety	Depth (cm)	Nitrates (ppm)		
			July	October	December
1	Koroneiki	0–30	27.3	32.9	14.8
		30–60	13.9	25.4	16.4
	Arbequina	0–30	64.3	53.4	25.7
		30–60	23.2	7.7	32.9
	Arbosana	0–30	44.6	44.3	21.8
		30–60	46.3	15.7	9.5
2	Picual	0–30	46.6	6.1	14.6
		30–60	19.3	55.5	22.1
	Arbequina	0–30	14.8	13.9	10.4
		30–60	22.7	10.0	11.4
	Moroccan picholine	0–30	37.1	19.5	30.0
		30–60	16.3	24.3	23.3
3	Arbequina	0–30	50.9	50.9	30.4
		30–60	20.0	18.9	47.7
	Koroneiki	0–30	16.8	44.3	27.5
		30–60	19.8	62.1	62.1
	Picual	0–30	53.0	42.9	22.7
		30–60	11.1	41.8	62.3

in the Arbequina variety compared to the other two varieties even though the three olive orchards have received the same nitrogen rate. For farmer 3, the Arbequina orchard recorded higher nitrate levels compared to the Koroneiki orchard, while both orchards have received the same nitrogen rate. A decrease in soil nitrate content was observed between October and December for the majority of olive orchards studied probably because of the abundant rains in November that increased nitrogen leaching in the soil (Figure 1).

Soil phosphorus contents in orchards of farmer 2 were higher as compared to other orchards during the three soil sampling dates. This could be due, first, to the high phosphorus rates used in these soils, and second, to the absence of limestone that could improve phosphorus availability for olive trees in these soils.

Soils in orchards of farmer 1 had the lowest phosphorus levels. This could be explained by the low phosphorus rate applied in these orchards. Soil phosphorus contents were almost the same for the different varieties for this farmer. For farmers 2 and 3, the highest levels of soil phosphorus were recorded in orchards

Table 5. Soil available phosphorus variations in the studied orchards.

Farmer	Variety	Depth (cm)	Available Phosphorus (mg P/kg)		
			July	October	December
1	Koroneiki	0–30	8.7	14.5	4.8
		30–60	3.9	9.4	4.1
	Arbequina	0–30	9.2	9.9	6.5
		30–60	3.9	3.1	2.4
	Arbosana	0–30	9.7	10.6	6.8
		30–60	4.6	5.8	3.9
2	Picual	0–30	19.4	37.2	14.0
		30–60	6.8	11.3	7.5
	Arbequina	0–30	39.2	65.2	17.4
		30–60	24.2	13.0	6.8
	Moroccan picholine	0–30	18.2	23.2	13.3
		30–60	10.4	19.8	5.1
3	Arbequina	0–30	35.1	50.4	25.2
		30–60	27.8	18.3	6.5
	Koroneiki	0–30	9.0	31.1	21.5
		30–60	6.1	17.1	6.1
	Picual	0–30	14.8	17.4	5.8
		30–60	7.7	13.0	3.4

Table 6. Change in exchangeable soil potassium in the studied orchards.

Farmer	Variety	Depth (cm)	Exchangeable Potassium (mg K/kg)		
			July	October	December
1	Koroneiki	0–30	230.0	281.3	312.8
		30–60	163.3	194.8	293.9
	Arbequina	0–30	475.9	179.9	185.7
		30–60	153.3	108.4	67.5
	Arbosana	0–30	369.4	476.2	303.9
		30–60	402.2	166.0	149.9
2	Picual	0–30	266.8	376.8	341.6
		30–60	143.4	151.1	72.5
	Arbequina	0–30	296.7	415.5	183.7
		30–60	238.0	135.2	100.3
	Moroccan picholine	0–30	255.9	342.0	261.2
		30–60	188.2	252.5	106.3
3	Arbequina	0–30	287.8	466.2	263.1
		30–60	235.0	172.0	75.5
	Koroneiki	0–30	130.4	353.9	181.7
		30–60	90.6	220.7	44.7
	Picual	0–30	200.1	234.6	149.9
		30–60	120.5	172.0	65.5

planted by the Arbequina variety as compared to the other two varieties. The soil phosphorus contents increased from July to October and decreased in December for all the tested orchards (Table 5).

The soil exchangeable potassium contents decreased between October and December in nearly all olive orchards (Table 6). Indeed, leaf potassium absorption peak in November (Table 7) and fruit potassium exportations could be the cause. Furthermore, the large amount of rainfall recorded during this period (Figure 1) could induce potassium leaching, which explains the decrease of soil potassium levels. An increase of soil exchangeable potassium contents between July and October was found. Potassium released has probably not been absorbed by olive trees because of foliar sprays that were made in September to satisfy the olive need for potassium.

Evolution of the olive leaf nutrients contents

Nitrogen

Leaf nitrogen content, measured in July, exceeded the threshold limit of sufficiency (1.5%) defined in the literature in the orchards of both farmers 1 and 3 and below this threshold level in the orchards of farmer 2. The evolution curves of the olive leaf nitrogen content followed almost the same shape for all varieties studied. The minimum value was recorded in February followed by a rise in April, probably

Table 7. Variation of olive leaf nitrogen, phosphorus and potassium concentrations, all varieties combined.

Measuring Period	N	P	K
January	1.5b	0.1bc	1.1bc
February	1.0c	0.2bc	1.2bc
April	1.9a	0.2ab	0.4d
May	1.5b	0.2a	0.9c
June	1.6b	0.2ab	1.6a
July	1.6b	0.1c	0.9c
August	1.5b	0.2abc	1.0c
September	1.4b	0.2ab	1.1bc
October	1.4b	0.2abc	1.4ab
November	1.5b	0.2ab	1.5a
December	1.5b	0.1bc	1.4ab

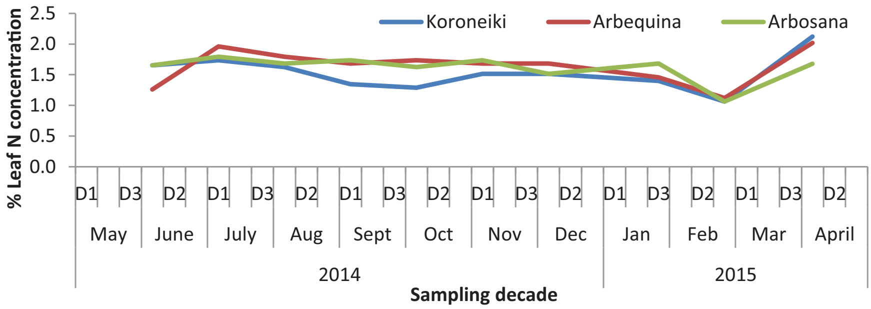

Figure 2. Evolution of the leaf nitrogen concentration of three olive varieties of farmer 1.

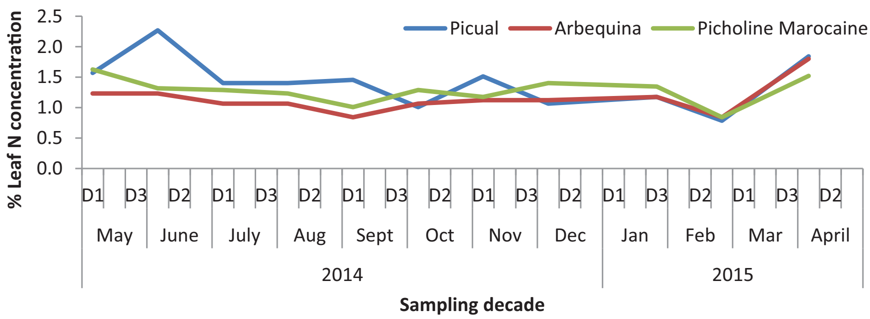

Figure 3. Evolution of the leaf nitrogen concentration of three olive varieties of farmer 2.

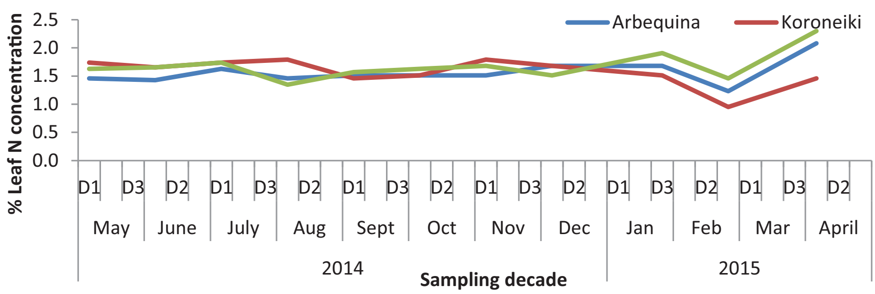

Figure 4. Evolution of the leaf nitrogen concentration of three olive varieties of farmer 3.

due to the nitrogen fertilizers made at this time that coincides with the start of the vegetative growth of the olive tree, and has stabilized thereafter (Figures 2–4). These results are not in concordance with those found by other researchers. According to Fernandez-Escobar, Moreno, and Garcia-creus (1999), the leaf nitrogen concentration started to decrease in June to reach the lowest value in August. Thereafter, during the fall, these leaves showed an increase in nitrogen concentration reaching a maximum at the end of the season. These leaf nitrogen levels remained almost constant until the following June. Perica (2001) reported that nitrogen content was high and stable in the winter and decreased significantly with the advancement of vegetative and reproductive development to reach the lowest value in summer (June, July and early August) coinciding with the early fruit development. Fernandez-Escobar, Moreno, and Sanchez-Zamora (2004) showed that the current season's leaves stored nitrogen in the "off year" (low production) of the alternating-bearing cycle and mobilized it during the following "on year," to support the new growth. The high accumulation of nitrogen in the “off year” was also observed by Fahmy (1958).

Phosphorus

Leaf phosphorus content measured during July were above the threshold limit of sufficiency (0.1%), defined in the literature, in all the studied orchards. The minimum leaf phosphorus content was registered in April for all three varieties of farmer 1 (Figure 5). It was noted that phosphorus levels in the Arbequina variety leaves were the highest compared to the other two olive varieties throughout the study period although the soil phosphorus contents and phosphorus applications were similar in the three orchards of this farmer. This means that the Arbequina phosphorus requirement is more important than that of Arbosana or Koroneiki varieties. For farmer 2, the minimum leaf phosphorus content

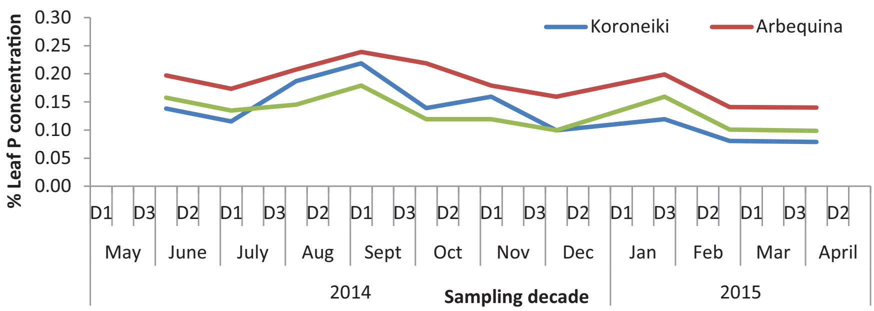

Figure 5. Evolution of the leaf phosphorus concentration of three olive varieties of farmer 1.

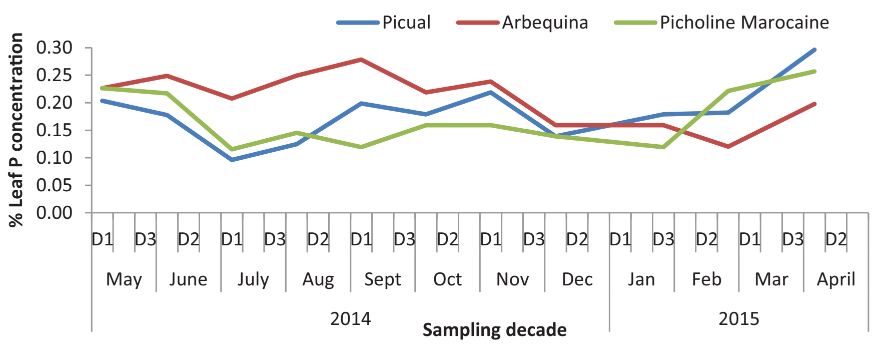

Figure 6. Evolution of the leaf phosphorus concentration of three olive varieties of farmer 2.

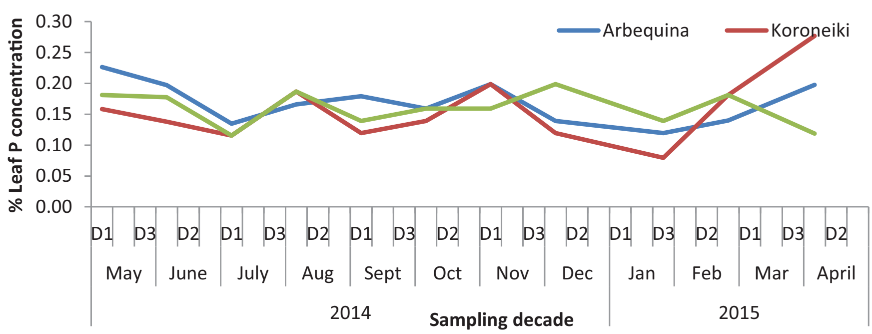

Figure 7. Evolution of the leaf phosphorus concentration of three olive varieties of farmer 3.

was observed in February in the Arbequina orchard and in July in the Picual and Moroccan Picholine orchards (Figure 6). For farmer 3, the minimum leaf phosphorus content was recorded in January for Koroneiki and Arbequina varieties and in July for the Picual variety (Figure 7). The Arbequina always showed a superiority concerning the leaf phosphorus content, compared to other varieties which have received the same phosphorus rate. It should be noted that soil phosphorus contents of Arbequina orchards were high relative to other orchards of farmers 2 and 3. Fahmy and Nasrallah (1959) found that the olive leaf phosphorus content was lowest in April and May. They also reported that the highest leaf phosphorus levels were recorded in January in the first year of experiment and in August the following year. However, Fernandez-Escobar, Moreno, and Garcia-creus (1999) have always found the minimum olive leaf phosphorus content in August or September and phosphorus accumulation in leaves during fall and winter, after an "off year."

The general appearance of these evolution curves of the olive leaf phosphorus content showed a gradual increase from April, decrease during June and July and then increases again to reach a peak in September followed by a progressive decrease and stabilization thereafter. Studies have shown that we have an improvement of the flowering and fruit set associated with the increase in phosphorus absorption (Erel et al. 2008).

Potassium

The leaf potassium content measured during July were higher than the threshold limit of sufficiency (0.8%), defined in the literature, in most orchards studied, with the exception of the Picual variety of farmers 2 and Koroneiki and Picual varieties of farmer 3. In the last three orchards, the leaf potassium levels, measured in July were below the threshold limit of sufficiency (0.8%) but above the threshold limit for deficiency (0.4%). Note that the soil potassium contents in these two orchards were low compared to the third orchard (Arbequina) of the same farmer during the three periods of soil sampling (Table 6). Also, potassium is not provided by farmer 3 for Koroneiki and was brought to a low dose for Picual (Table 2). For Picual of farmer 2, despite considerable amount of potassium provided in this orchard (Table 2), olive leaf potassium uptake has been low because of the low soil potassium content (Table 6) taking into consideration the high soil clay content (Table 3).

The evolution of the leaf potassium concentration has followed roughly the same pace for all olive varieties studied. Indeed, the minimum value was recorded in April where there was an increase with peaks that were different from one orchard to another. For Arbosana and Arbequina varieties of farmer 1, the leaf potassium concentrations increased from April to reach a peak in November and December, respectively, and they decreased to reach a minimum in April (Figure 8). This decrease after harvest can be explained by the low potassium need of olive tree during this dormancy period. For the Koroneiki variety of the same farmer, the curve followed almost the same shape with a peak in June. For farmer 2, the peak marked by Picual in September (Figure 9) is due to relatively high intake of potassium made in August (30 unit K_2O/ha/month) which was available for olive. For the Arbequina, potassium intake made in April, May and June could explain the peak recorded in June and from which, the leaf potassium concentration began to drop. Subsequently, the potassium applications that followed (30 units of K_20/ha/month) helped to straighten the curve again in October and November. For farmer 3, the leaf

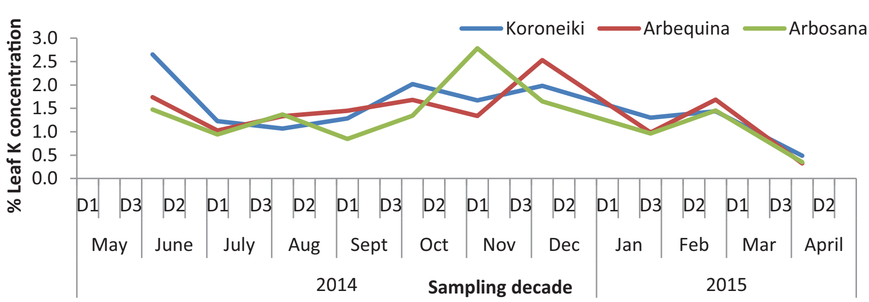

Figure 8. Evolution of the leaf potassium concentration of three olive varieties of farmer 1.

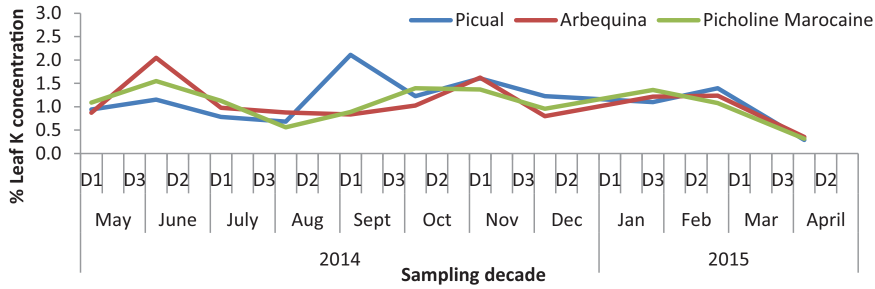

Figure 9. Evolution of leaf potassium concentration of three olive varieties of farmer 2.

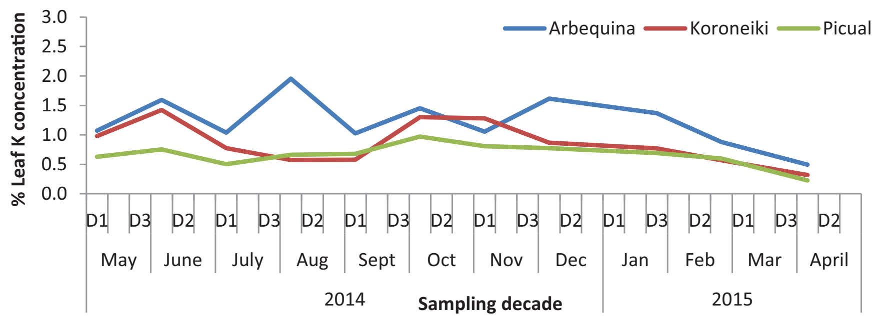

Figure 10. Evolution of the leaf potassium concentration of three olive varieties of farmer 3.

potassium concentration for Arbequina decreased during February and March to reach a minimum in April and it increased to reach a peak in June then it decreased later to resume its elevation with other peaks in August, September and December (Figure 10). For the Picual, the leaf potassium concentration increased between April and June to decrease in July before rising again to reach a peak in October. Subsequently, it began to decrease gradually from October to reach a minimum in April.

In general, the olive leaf potassium absorption is important during the period from September to December. In fact, potassium is necessary to the later stages of crop growth for fruit ripening (Boulal, Sikaoui, and El Gharous 2013). This is where the olive need for potassium is generally high. The high accumulation of potassium in the olive leaves after an "off" year and its rapid decline after March of "on year" suggests large potassium demand by the reproductive structures of the olive tree (Fernandez-Escobar, Moreno, and Garcia-creus 1999). Other researchers (Ryugo 1988; Shear and Faust 1980) reported that the leaf potassium concentration declines in most tree crops as the season progresses. Fernandez-Escobar, Moreno, and Garcia-creus (1999) found that the leaf potassium concentration of the current season's leaves declined gradually since the beginning of the season (March) to August and has maintained these values approximately in the fall and the following year with the exception of a peak in March.

Effect of olive variety and the sampling period on the leaf nitrogen, phosphorus and potassium concentration

In this part, we studied the difference between all measurements made at different times for olive leaf nitrogen, phosphorus and potassium concentrations.

Leaf nitrogen content has reached a peak in April and decreased to a minimum in February then it remained stable in all other leaf sampling periods (Table 7). For phosphorus, the olive leaf content recorded the minimum level in July and the maximum level in May. The lowest leaf potassium content

Table 8. The yields achieved in orchards studied during the campaign.

Farmer	Orchard	Variety	Yield (t/ha)
1	1	Koroneiki	6.5
	2	Arbequina	5.0
	3	Arbosana	10.0
2	4	Picual	2.5
	5	Arbequina	3.0
	6	Moroccan picholine	4.0
3	7	Arbequina	8.7
	8	Koroneiki	7.4
	9	Picual	1.6

was recorded in April, while the maximum level was recorded in June and November, coinciding with the high olive need period for potassium. Statistical analysis of the data showed a highly significant effect of leaf sampling period on their nitrogen and potassium content (Table 7). However, this effect was not significant on the leaf phosphorus content.

We also studied the variety effect that appears to be non-significant for all three measured parameters (leaf N, P and K contents). Chatzistathis and Therios (2009) reported no differences in leaf potassium levels between the two olive varieties studied by Koroneiki and Kothreiki.

Yield olives

Yields recorded in the orchards of farmer 2, especially for Arbequina and Picual varieties, were low compared to the previous year. This could be explained by the alternating phenomenon (Table 8). Indeed, the yields recorded for the previous year were 13 t/ha; 14 t/ha and 8 t/ha, respectively, for the Picual, Arbequina and Moroccan Picholine varieties. This phenomenon of alternation has also affected yields in the orchards of farmer 1, especially for the Arbequina and Koroneiki varieties. Indeed, the yields for the previous year were 12 t/ha; 12.5 t/ha and 10 t/ha, respectively, for the Arbequina, the Koroneiki and Arbosana varieties. In addition, part of the orchard (almost half) of Arbequina variety of farmer 1 had no production due mainly to the pruning it has suffered. The low yield recorded by the Picual variety of farmer 3 could be explained by the age of the orchard which was in its second year of production (Table 8).

It was observed that the weaker olive yields were recorded in the orchards of farmer 2 (Table 8) where the leaf nitrogen levels were below standards listed in the literature. Considering the year 2014 as an "off year," given the yields achieved in these orchards, which are low in comparison with the previous year (2013), could explain the leaf macronutrients concentrations recorded. Indeed, Fernandez-Escobar, Moreno, and Garcia-creus (1999) reported that the olive leaf nitrogen, phosphorus and potassium contents were affected by crop load, showing lower values in an "on year."

Conclusions

The olive leaf nitrogen concentration measured in July were above the threshold limit for sufficiency (1.5%) in the orchard of farmers 1 and 3 and below this threshold in the orchards of farmer 2. The olive leaf phosphorus levels during July were above the threshold limit for sufficiency (0.1%) in all studied orchards. The olive leaf potassium concentrations measured in July were above the threshold limit for sufficiency (0.8%) in the majority of the studied orchards, except Picual variety of farmer 2 and Picual and Koroneiki varieties of farmer 3 where these levels have been below this threshold but above the threshold limit for deficiency (0.4%). Indeed, the soil potassium contents in these two orchards were low compared to the third orchard (Arbequina) of farmer 3. Also, the potassium rate provided by the farmer was low for the Picual variety and zero for Koroneiki. For the Picual variety of farmer 2, the observed potassium deficiency may be due to the high soil clay content that has hampered the leaf absorption of potassium provided in this orchard.

The olive leaf macronutrients contents have varied over time throughout the crop cycle. The evolution of leaf nitrogen concentration curves followed almost the same shape for all varieties studied. The minimum leaf nitrogen content was recorded in February followed by a rise in April, probably due to the nitrogen fertilizers made at this time that coincides with the start of the vegetative growth of the olive tree to stabilize thereafter. Olive leaves have maintained almost the same nitrogen content throughout the crop cycle indicating a continuing olive need for nitrogen. The general shape of the evolution curves of leaf phosphorus content showed a gradual rise from April to decrease during June and July followed by an increase again, reaching a peak in September and a progressive decrease and stabilization thereafter. A higher phosphorus absorption by the culture was therefore recorded during periods of flowering and fruit magnification that can be considered as periods of high olive need for phosphorus. For potassium, the olive leaf contents were high between September and December, which represents the period of high olive need for potassium.

The study found no variety effect on the olive leaf nitrogen, phosphorus and potassium contents. But very highly significant differences were found between the different sampling times on the leaf nitrogen and potassium concentrations. However, leaf phosphorus content determined during different periods was statistically equal. These results confirm the importance of nitrogen and potassium for olive tree following its high requirements of these two nutrients during its development cycle, relative to phosphorus that is absorbed in small amounts by the crop.

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References

Alcala, A. R., and D. Barranco. 1992. Prediction of flowering time in olive for the Cordoba olive collection. *HortScience* 27:1205–7.

Allison, L. E. 1965. Organic carbon. In *Methods of soil analysis. Part II, chap. 90*, ed. C. Dans and A. Black, 1372–6. Madison: American Society of Agronomy. Inc.

Benton, J. 1985. Soil testing and plant analysis: Guides to the fertilization of horticultural crops. *Horticultural Reviews* 7:1–68.

Bignami, C., S. Natali, C. Menna, and G. Peruzzi. 1994. Growth and phenology of some olive cultivars in central Italy. *Acta Horticulturae* 356:106–9. doi:10.17660/ActaHortic.1994.356.23.

Boulal, H., L. Sikaoui, and M. El Gharous. 2013. Nutrient management: A new option for olive orchards in North Africa. *Better Crops with Plant Food* 97 (4):21–22.

Bouma, J. 1997. Precision agriculture: Introduction to the spatial and temporal variability of environmental quality. In *Precision agriculture: Spatial and temporal variability of environmental quality. Ciba Foundation Symposium, 210*, ed. J. V. Lake, G. R. Bock, and J. A. Goode, 5–17. Wageningen, the Netherlands: Wiley.

Chapman, H. D. 1965. Cation-exchange capacity. In *Methods of soil analysis. Part II, Chap. 57 and 58*, ed. C. Dans and A. Black, 891–903. Madison: American Society of Agronomy Inc.

Chartzoulakis, K., M. Loupassaki, M. Bertaki, and I. Androulakis. 2002. Effects of NaCl salinity on growth, ion content and CO_2 assimilation rate of six olive cultivars. *Scientia Horticulturae* 96 (1):235–47. doi:10.1016/S0304-4238(02)00067-5.

Chatzistathis, T., and I. Threrios. 2009. Differential uptake, distribution within tissues, a use efficiency of manganese, iron, and zinc by olive cultivars Kotheiki and Koroneiki. *HortScience* 44 (7):1994–9.

Cimato, A., C. Cantini, and G. Sani. 1990. Climate-phenology relationships on olive cv. *Frantoio. Acta Horticulturae* 286:171–4. doi:10.17660/ActaHortic.1990.286.33.

Damon, P. M., and Z. Rengel. 2007. Wheat genotypes differ in potassium efficiency under glasshouse and field conditions. *Australian Journal of Agricultural Research* 58:816–25. doi:10.1071/AR06402.

Day, P. R. 1965. Particle fractionation and particle-size analysis. In *Methods of soil analysis, Agron. N°. 9. Part 1. Physical and mineralogical properties*, ed. C. A. Black, 546–66. Madison, USA: American Society of Agronomy.

Demiral, M. A. 2004. Effect of cultivars on uptake and translocation of sodium and chloride in olive (Olea europea L.) plant. *Adnan Menders University Ziraat Fakultesi Dergisi* 1 (2):5–12.

Dimassi, K., I. Therios, and A. Passalis. 1999. Genotypic effect on leaf mineral levels of 17 olive cultivars grown in Greese. *Acta Horticulture* 474:345–8. doi:10.17660/ActaHortic.1999.474.71.

El Gharous, M., M. El Amrani, and K. El Mjahed. 1995. *Manuel des Méthodes d'Analyses de Sol et de la Plante*. Morocco: Aridoculture, Institut National de la Recherche Agronomique.

Erel, R., R. Dag, A. Ben-Gal, A. Schwartz, and U. Yermiyahu. 2008. Flowering and fruit set of olive trees in response to nitrogen, phosphorus, and potassium. *Journal of the American Society for Horticultural Science* 133 (5):639–47.

Fahmy, I. 1958. Changes in carbohydrate and nitrogen content of souri olive leaves in relation to alternate bearing. *Proceeding of American Society of Horticultural Science* 72:252–6.

Fahmy, I., S. Nasrallah. 1959. Changes in macro-nutrient elements of souri olive leaves in alternate bearing years. *Proceeding of American Society of Horticultural Science* 74:372–7.

Fernandez_Escobar, R., R. Moreno, and M. Garcia-creus. 1999. Seasonal changes of mineral nutrients in olive leaf during the alternative-bearing cycle. *Scientia Horticulturae* 82:25–45. doi:10.1016/S0304-4238(99)00045-X.

Fernandez-Escobar, R., M. Benlloch, C. Navarro, and G. C. Martin. 1992. The time of floral induction in the olive. *Journal of the American Society for Horticultural Science* 117:304–7.

Fernandez-Escobar, R., R. Moreno, and M. A. Sanchez-Zamora. 2004. Nitrogen dynamics in the olive bearing shoot. *HortScience* 39 (6):1406–11.

Hach Company. 1992. *Soil and irrigation water interpretation manual*. USA: Hach.

Hartman, H. T. 1951. Time of floral differentiation of the olive in California. *Botanical Gazette* 112:323–7. doi:10.1086/335668.

Jordao, P. V., M. E. Marcelo, and M. S. L. Centeno. 1999. Effect of cultivar on leaf-mineral composition of olive tree. *Acta Horticulturae* 474:349–52. doi:10.17660/ActaHortic.1999.474.72.

Khoshgoftarmanesh, A. H., R. Schulin, R. L. Chaney, B. Daneshbakhsh, and M. Afyuni. 2010. Micronutrient-efficient genotypes for crop yield and nutritional quality in sustainable agriculture. *A review. Agronomy for Sustainable Development.* 30:83–107. doi:10.1051/agro/2009017.

Little, R. C., G. A. Milliken, W. W. Stroup, W. D. Wolfinger, and O. Schabenberger. 2006. *SAS for mixed models*, 2nd ed. Cary, NC. USA: SAS Institute Inc.

Loupassaki, M. H., K. S. Chartzoulakis, N. B. Digalaki, and I. I. Androulakis. 2002. Effects of salt stress on concentration of nitrogen, phosphorus, potassium, calcium, magnesium, and sodium in leaves, shoots, and roots of six olive cultivars. *Journal of Plant Nutrition* 25 (11):2457–82. doi:10.1081/PLN-120014707.

Marschner, H. 1995. *Mineral nutrition of higher plants*. London: Academic Press.

Michelakis, N. 2002. Olive orchard management: Advances and problems. *Acta Horticulturae* 586:239–45. doi:10.17660/ActaHortic.2002.586.45.

Olsen, S. R., C. V. Cole, F. S. Watanabe, and L. A. Dean. 1954. *Estimation of available phosphorus in soils by extraction with bicarbonate*. USA: Department of Agriculture.

Paskovic, I., S. Perica, M. Pecina, K. Hancevic, M. P. Paskovic, and M. H. Custic. 2013. Leaf mineral concentration of five olive cultivars grown on calcareous soil. *Journal of Central European Agriculture* 14 (4):1488–95.

Perica, S. 2001. Seasonal fluctuation and intracanopy variation in leaf nitrogen level in olive. *Journal of Plant Nutrition* 24 (4&5):779–87. doi:10.1081/PLN-100103670.

Rallo, L., and R. Fernandez-Escobar. 1985. Influence of cultivar and flower thinning within the inflorescence on competition among olive fruit. *Journal of the American Society for Horticultural Science* 110:303–8.

Ryan, J., S. Garabet, K. Harmsen, and A. Rashid. 1996. *A soil and plant analysis manual adapted for the West Asia and North Africa region*, 140p. Aleppo, Syria: ICARDA.

Ryugo, K. 1988. *Fruit culture, its science and art*. New York: Wiley.

Shear, C. B., and M. Faust. 1980. Nutritional ranges in deciduous tree fruits and nuts. *Horticultural Reviews* 2:142–63.

Shuxin, T. U., S. Jinghe, G. Zhifen, H. Ming, and Z. Ping. 2000. Genotypic variations in potassium absorption and utilization by amaranthus spp. *Pedosphere* 10:363–72.

Sims James, R., and D. Jackson Grant. 1971. Rapid Analysis of Soil Nitrate with Chromotropic Acid 1. *Soil Science Society of America Journal* 35 (4):603–606.

Therios, I. N., and N. D. Misopolinos. 1988. Genotypic response to sodium chloride salinity of four major olive cultivars (Olea europea L.). *Plant and Soil* 106 (1):105–11. doi:10.1007/BF02371201.

Therios, I. N., and S. D. Sakelariadis. 1988. Effect of nitrogen form on growth and mineral composition of olive plants (Olea europea L.). *Scientia Horticulturae* 35:167–77. doi:10.1016/0304-4238(88)90110-0.

Toplu, C., V. Uygur, and E. Yildiz. 2009. Leaf mineral composition of olive varieties and their relation to yield and adaptation ability. *Journal of Plant Nutrition* 32:1560–73. doi:10.1080/01904160903094321.

White, M. C., R. L. Chaney, and A. M. Decker. 1979. Differential cultivar tolerance in soybean to phytotoxic levels of soil Zn. II. Range of Zn additions and the uptake and translocation of Zn, Mn, Fe and P. *Agronomy Journal* 71 (1): 126–31. doi:10.2134/agronj1979.00021962007100010032x.