

1 **Diagnosis of soil fertility and nutritional status of** 2 **the olive tree in central Morocco**

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ABSTRACT

This study was conducted in 2009/2010 with 58 olive orchards randomly selected at the Sais region. The main objectives of this work are: i) Analysis of fertilization practices adopted by olive growers in the study region; ii) determining the soil fertility levels of the olive orchards; iii) The assessment of nutritional status of these olive orchards by leaf nitrogen, phosphorus and potassium analyses. Composite soil samples were collected from two depths (0-30 cm and 30-60 cm) during the December/January period. Composite leaf samples were also collected from the same orchards and in the same period as soil sampling. Surveys were conducted on these orchards to collect data for characterization and analysis of different fertilization modes adopted in relation to olive yield. The surveys have revealed shortcomings as regards fertilization practices of olive cultivation. Indeed, approximately 48.3% of the farmers surveyed provide no fertilizer for their olive trees. The laboratory analyzes of soil and leaf samples collected in these orchards have confirmed this. The study showed no correlation between the olive yield and soil fertility parameters (soil nitrate or phosphorus or exchangeable potassium contents). Also, the olive yield was not correlated with the leaf nitrogen or phosphorus or potassium contents. The relationship between the olive nutrition parameters and the soil fertility parameters, at the 0-30 cm horizon in the olive groves showed that olive leaf parameters were not linked to those of soil fertility. However, much of the leaf nitrogen content (about half) has been explained by the soil nitrate content in irrigated orchards. The determination of the olive tree fertilization standards is a necessary step for a rational management of fertilizers for the olive trees. These standards should be developed through field trials.

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Keywords: Olea Europea, Nitrogen, Phosphorus, Potassium, Soil, Leaves, Surveys.

9 **1. INTRODUCTION**

10 The olive tree is the main fruit species cultivated in Morocco with a large proportion of its
11 total area located in rainfed areas. However, the olive yields are still below the olive sector
12 potential. Indeed, the weather, in the drought case, and weak technical management are the
13 main factors generating the low productivity registered for olives. Fertilization is one of the
14 techniques not mastered by the majority of Moroccan growers. This work has as main
15 objectives:

- 16 • Analysis of fertilization practices adopted by farmers at Sais region, in center of
17 Morocco. This analysis will be based on the processing of data collected by surveys
18 with a representative sample of farms in the study area
- 19 • Determination of soil fertility levels in the olive orchards;
- 20 • The assessment of nutritional status of these olive orchards by leaf nitrogen,
21 phosphorus and potassium analyses.

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23 **2. MATERIAL AND METHODS**

24 This study was conducted at Sais region, through surveys, soil testing and leaf analyzes.

25 **2.1. Surveys**

26 58 olive orchards, distributed on the territory of the study area (Moulay Driss, Mhaya,
27 Ain Jemaa, Dkhissa, Agourai, Ras Jerry...etc.) were chosen at random. A pilot survey was
28 developed and served as a support for data collection in the field. These relate to the culture
29 system, planting density, tree age, variety, soil type, and the technical route of

culture including mineral and organic fertilization adopted by farmers. These data were used for the characterization of the sampled groves and analysis of different modes of fertilization adopted in relation to the olive yield.

2.2. Soil Testing

At these selected orchards, composite soil samples were collected in the diagonal method, at two depths 0-30 cm and 30-60 cm, in the December/January period. They were the subject of analyses for their characterization (limestone, organic matter, pH) and the determination of their fertility levels (nitrogen, phosphorus and potassium). The analytical methods used are: extraction by chromotropic acid for nitrates, Olsen for phosphorus, Walkley and Black for organic matter, Drouineau for active limestone extraction and ammonium acetate for potassium.

2.3. Leaves analyzes

Composite leaf samples were also collected from the same orchards and in the same period of soil sampling. The nitrogen and phosphorus mineralization was created by concentrated sulfuric acid and the potassium with perchloric acid. The leaf nitrogen contents were determined by Kjeldahl distillation, those of phosphorus by colorimetry and those of potassium by photometrically.

3. RESULTS AND DISCUSSION

3.1. Characterization of olive orchards

3.1.1 Age

The sample is characterized by different age groups ranging from a minimum of 4 years to 70 years. Young orchards whose age does not exceed 10 years represent only 5% of all surveyed orchards while older orchards (> 40 years) have a part of 35% of the studied orchards. The orchards belonging to the age group between 11 and 40 years account for more than half (60%) of all surveyed groves (Figure 1).

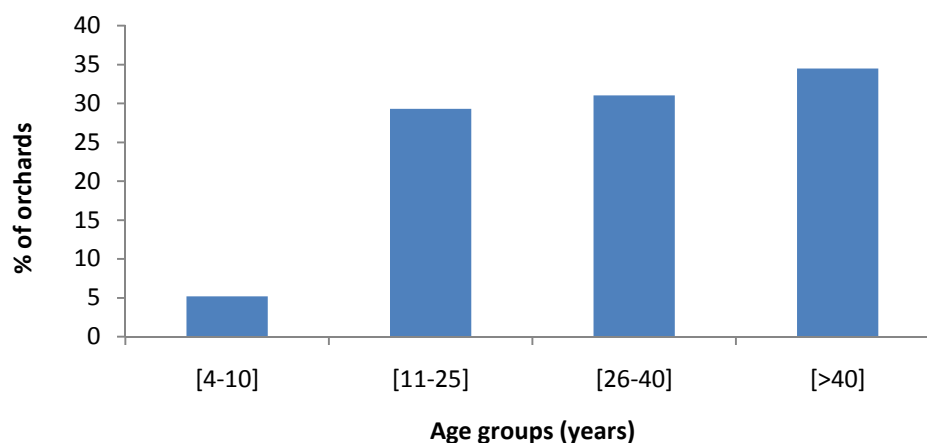


Figure 1. Olive orchards distribution according to their ages

3.1.2. Driving Mode

More than half of the surveyed groves (57%) are conducted in rainfed conditions (Figure 2). At irrigated orchards, the gravity irrigation system dominates with a part of 24% of all surveyed orchards. As for drip irrigation, it is only present in 19% of studied farms.

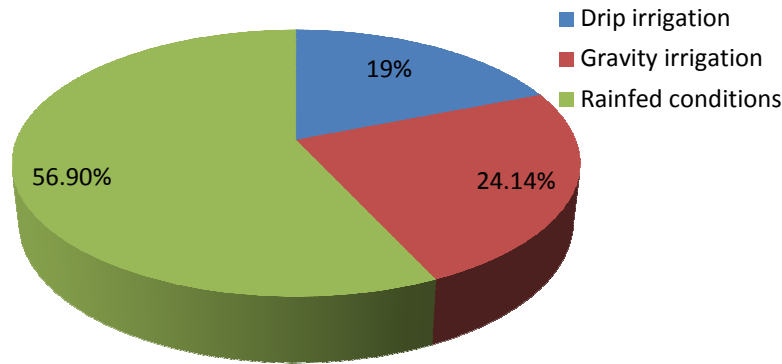


Figure 2. Olive orchards distribution according to the driving mode

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3.1.3. Density

Most plantations (84.5%) have a planting density between 100 and 350 trees/ha (Figure 3). Extensive densities (<100 trees/ha) represent only 5% of respondents orchards. The rest (10%) is represented by orchards with the density exceeds 350 trees/ha.

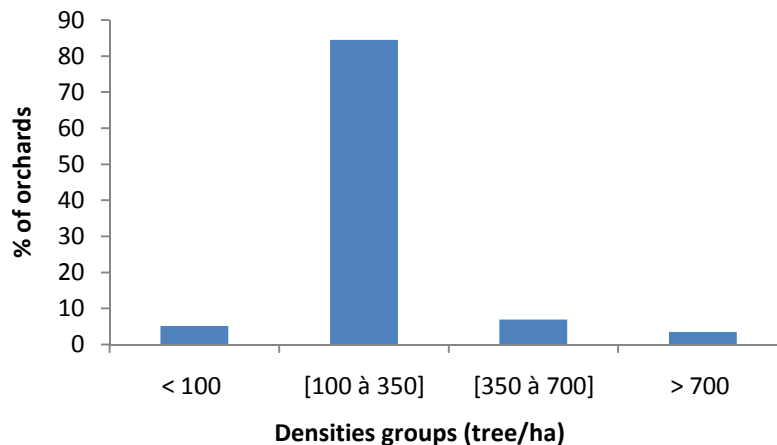


Figure 3. Olive orchards distribution according to their planting densities

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3.1.4. Intercropping

The percentage of surveyed orchards where the olive tree was associated with intercropping was important (48.3%). The species used by farmers are mainly cereals (barley, wheat, and oats); legumes (Lentil, bean, peas, chickpeas, and beans); the vegetable crops (tomato, potato, onion, turnip, zucchini, cauliflower, pepper); fodder (alfalfa).

3.1.5. Fertilization

48.3% of surveyed growers use no mineral fertilizer for their olive trees. The main fertilizers used by farmers are ammonium nitrate, sulphate of ammonia, diammonium phosphate, phosphate monoammonium, potassium nitrate, urea and some fertilizer formulas such as 14/28/14, the 10/25/20 / S and the 0/16/30 / S. 41.4% of farmers do not use manure. The type of manure used in these orchards is dominated by sheep/beef mixture (Table 1).

Table 1. Use of manure by olive growers.

Manure	% of orchards
Sheep manure	12.1
Cattle manure	1.7
Sheep manure + Cattle manure	44.8
No	41.4

3.1.6. Variety

The dominant variety in olive orchards studied was the Moroccan Picholine with a percentage of 98.3% of the total surveyed orchards.

3.1.7. Yield

The yields reported by growers surveyed vary widely from one farm to another. They vary between 0 and 14.3 t/ha. Olive trees under drip irrigation recorded an average yield of 5.1 t/ha, those led by gravity irrigation recorded an average yield of 1.9 t/ha. For orchards in rainfed conditions, the average yield is 1.8 t/ha.

3.2. Assessment of soil fertility of olive orchards sampled

Based on analyzes of samples taken from soil, the majority of these are basic, calcareous, and largely poor to moderately filled in organic matter.

3.2.1. Organic matter content

The organic matter content was highly variable from one floor to another. It was between 0.1 and 4.5% for the soil layer 0-30 cm, and between 0.04 and 2.7% for the soil layer 30-60 cm. The surface horizon is usually provided by organic matter (mean = 2.1%) than the 30-60 cm horizon (mean = 1.3%).

3.2.2. Active limestone content

The average content of active limestone was 12.5% and 10.9%, respectively, for the soil layers 0-30 cm and 30-60 cm. It varied between 0 and 18% for the 0-30 cm horizon and 0 to 19.8% for the 30-60 cm horizon.

3.2.3. pH

The soil pH ranged from 6.3 to 8.8 for the 0-30 cm horizon and 6.4 to 8.9 for the 30-60 cm horizon. Alkaline soils predominate in the olive orchards studied. Indeed, in the two soil layers 0-30 and 30-60 cm, 96.6% and 93.1% of soils, respectively, are basic soils according to standards set by Chafai (2003) (Figure 4).

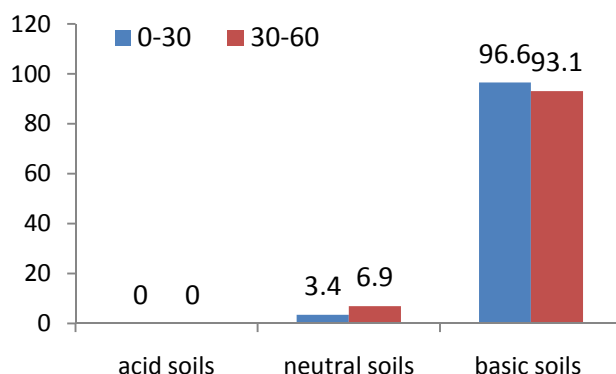


Figure 4. pH of soil sampled groves

3.2.4. Soil fertility

For a given site, soil fertility levels have declined in the lower layers of the soil in comparison to the topsoil (Tubéilh and al. 2014). In our study, the soil nitrate levels ranged between 1.8

and 71.4 mg.kg⁻¹ and between 1.5 and 40 mg.kg⁻¹, respectively, for the soil layers 0-30 cm and 30-60 cm. For phosphorus, soils showed levels ranging from 1.3 to 59.3 mg.kg⁻¹ for the 0-30 cm layer and from 1.4 to 41.7 mg.kg⁻¹ for the 30-60 cm layer. The soil potassium ranged between 43.8 and 1456.5 mg.kg⁻¹ for the 0-30 cm horizon, and between 34.4 and 997.7 mg.kg⁻¹ for 30-60 cm horizon. The soil P and K levels are higher than the values found in other studies in Tunisia, Syria and Spain. Indeed, in a soil fertility survey of olive trees in SidiBouzid (northwest Tunisia), Gargouri and Mhiri (2002) reported values between 6 and 19.9 mg.kg⁻¹ to P (average of 11.8 mg.kg⁻¹) and from 90 to 270 mg.kg⁻¹ for K (average of 133 mg.kg⁻¹) in the 0-30 cm soil layer. In Syria, Tubeileh and al. (2014) reported in the topsoil (0-20 cm), the P values ranging from 2.4 to 23.2 mg.kg⁻¹ and K values between 14 and 386 mg.kg⁻¹. Restrepo-Diaz and al. (2008) reported, in Andalusia, soil potassium contents between 61 and 171 mg.kg⁻¹ in the 0-30 cm layer. Pa against, Llamas Ferreira (1984) found, in the Andalusian olive, soil potassium contents between 105 and 565 mg.kg⁻¹ and soil phosphorus contents between 60 and 162 mg.kg⁻¹ in the 0-30 cm layer.

3.3. Determination of the nutritional status of the olive orchards

The olive leaf analysis revealed low leaf nitrogen, phosphorus and potassium contents which have varied, respectively from 0.224 to 0.602%; from 0.036 to 0.255 and from 0.338 to 1.078%. Gargouri and Mhiri (2002) found values between 0.058% and 0.14% for P and between 0.43% and 0.93% for K. Tubeileh and al. (2014) reported values ranging from 0.95 to 1.56% for nitrogen, from 0.07 to 0.14% for phosphorus and from 0.12 to 1.07 for potassium. The leaf mineral contents were in most cases lower than the deficiency levels reported in the literature. Indeed, all of the studied orchards require nitrogen inputs, according to the fertilization standards defined by Marino Fernandez-Escobar (1997) and Fernandez-Escobar et al. (1999) (Table 2). 91% of orchards need potassium fertilization. As for phosphorus, it was less of a problem compared with nitrogen and potassium as about a third of sampled soils need a supply of phosphorus.

Table 2. Percentage orchards should be fertilized based on leaf analyzes.

mineral element	% of orchards
N	100 %
P	36.2 %
K	91.4 %

3.4. Relations between the parameters studied

The data statistical analysis showed no correlation between the olive yield and soil nitrate or phosphorus or exchangeable potassium contents (Table 3). Tubeileh and al. (2014) in their study in Syria, found that the most important factor was the amount of potassium available in the root zone explaining the two-thirds of the yield variability ($R^2 = 68\%$) followed by total nitrogen in the root zone that was ranked second with 58% of the explained variability and mineral nitrogen in the root zone, which explained 44% of variability (significant correlation).

Table 3. Regressions between the olive yield and the soil nitrates, phosphorus and potassium contents, according to the three driving modes of olive groves.

Yield	Rainfed conditions		Gravity irrigation		Drip irrigation	
	Model	R ²	Model	R ²	Model	R ²

Soil nitrates	$y = -0,0005x^2 + 0,0257x + 1,5725$	$R^2 = 0,0067$	$y = 2,96e-0,036x$	$R^2 = 0,3033$	$y = -0,0007x^2 - 0,0638x + 6,6668$	$R^2 = 0,076$
Soil phosphorus	$y = 0,0002x^2 - 0,0365x + 2,3283$	$R^2 = 0,0255$	$y = -0,0032x^2 + 0,1696x + 0,3605$	$R^2 = 0,1802$	$y = -0,017x^2 + 0,9779x - 3,967$	$R^2 = 0,4261$
Soil potassium	$y = 1E-06x^2 - 0,0013x + 2,0524$	$R^2 = 0,0062$	$y = -1E-05x^2 + 0,0087x + 0,4994$	$R^2 = 0,1166$	$y = 0,0002x^2 - 0,094x + 17,129$	$R^2 = 0,1734$

The olive yield is not correlated with the leaf nitrogen or phosphorus or potassium contents (Table 4). Tubeileh and al. (2014) found the same results for nitrogen and phosphorus when they noted a significant correlation between the olive yield and the leaf potassium contents with 26% of the explained variability. A strong negative correlation was observed by Jasrotia and al. (1999) between the olive yield and leaf phosphorus and potassium content.

Table 4. Regression between the olive yield and the leaf mineral contents, according to the three driving modes of olive groves.

Yield	Rainfed conditions		Gravity irrigation		Drip irrigation	
	Model	R^2	Model	R^2	Model	R^2
% Leaf nitrogen	$y = -8,8455x^2 + 8,6368x - 0,1061$	$R^2 = 0,0045$	$y = 184,75x^2 - 118,7x + 20,193$	$R^2 = 0,3515$	$y = -166,6x^2 + 125,2x - 17,805$	$R^2 = 0,0299$
% Leafphosphorus	$y = 193,49x^2 - 38,882x + 3,4603$	$R^2 = 0,0327$	$y = 300,44x^2 - 68,193x + 4,9764$	$R^2 = 0,6275$	$y = -720,24x^2 + 253,39x - 13,875$	$R^2 = 0,1631$
% Leaf potassium	$y = -12,073x^2 + 16,425x - 3,3019$	$R^2 = 0,0299$	$y = 4,2404e-1,676x$	$R^2 = 0,3184$	$y = -185,75x^2 + 201,21x - 46,614$	$R^2 = 0,2352$

We also studied the relationship between the olive leaf nitrogen, phosphorus and potassium contents, at the 58 sampled orchards, and soil nitrate, available phosphorus and

exchangeable potassium contents, at the 0-30 cm horizon. Figures 5, 6 and 7 present regressions curves produced between these parameters for each driving mode orchards adopted by farmers (rainfed conditions, gravity irrigation and drip irrigation). These have shown that nutrition parameters of olive leaves are not linked to those of soil fertility. With the exception of nitrogen where much (about half) of the leaf content has been explained by the soil nitrate content but only in irrigated orchards (Figure 5). Note that all these regressions are not statistically significant. Gargouri and Mhiri (2002) also showed no relationship between the olive leaf phosphorus and potassium content and the soil phosphorus and potassium content, respectively.

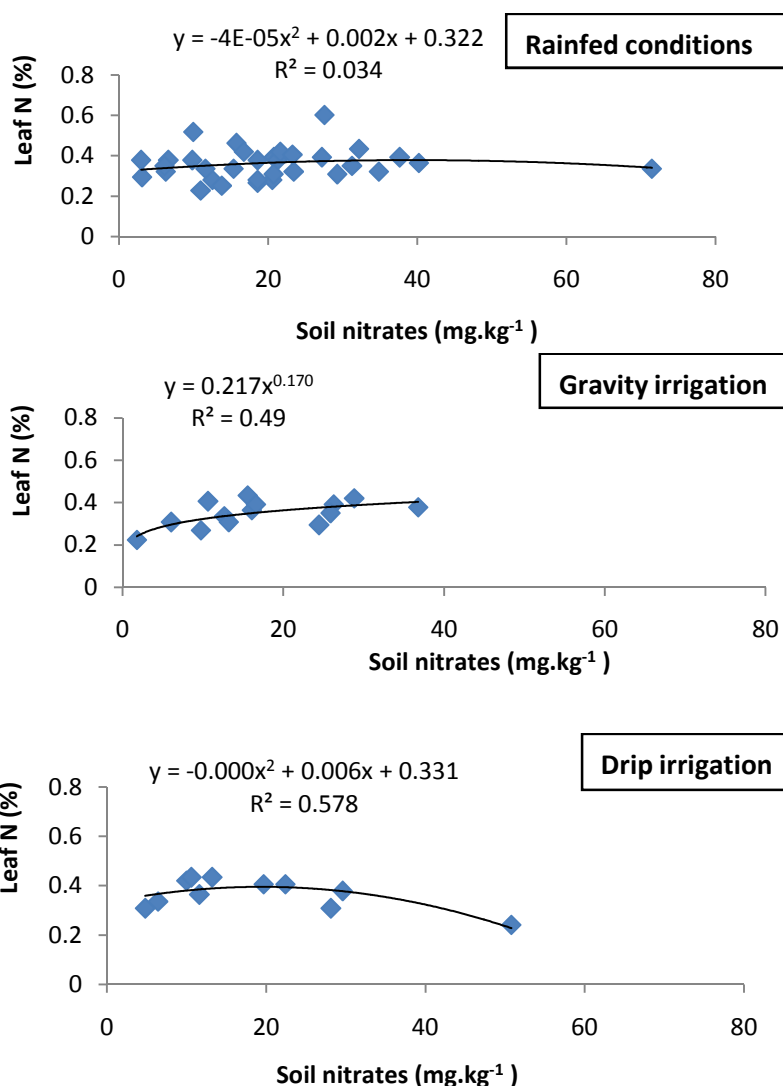


Figure5.Evolution of theleaf nitrogencontentaccording to the soil nitratecontent (0-30cm) for the three driving modesof the studiedorchards.

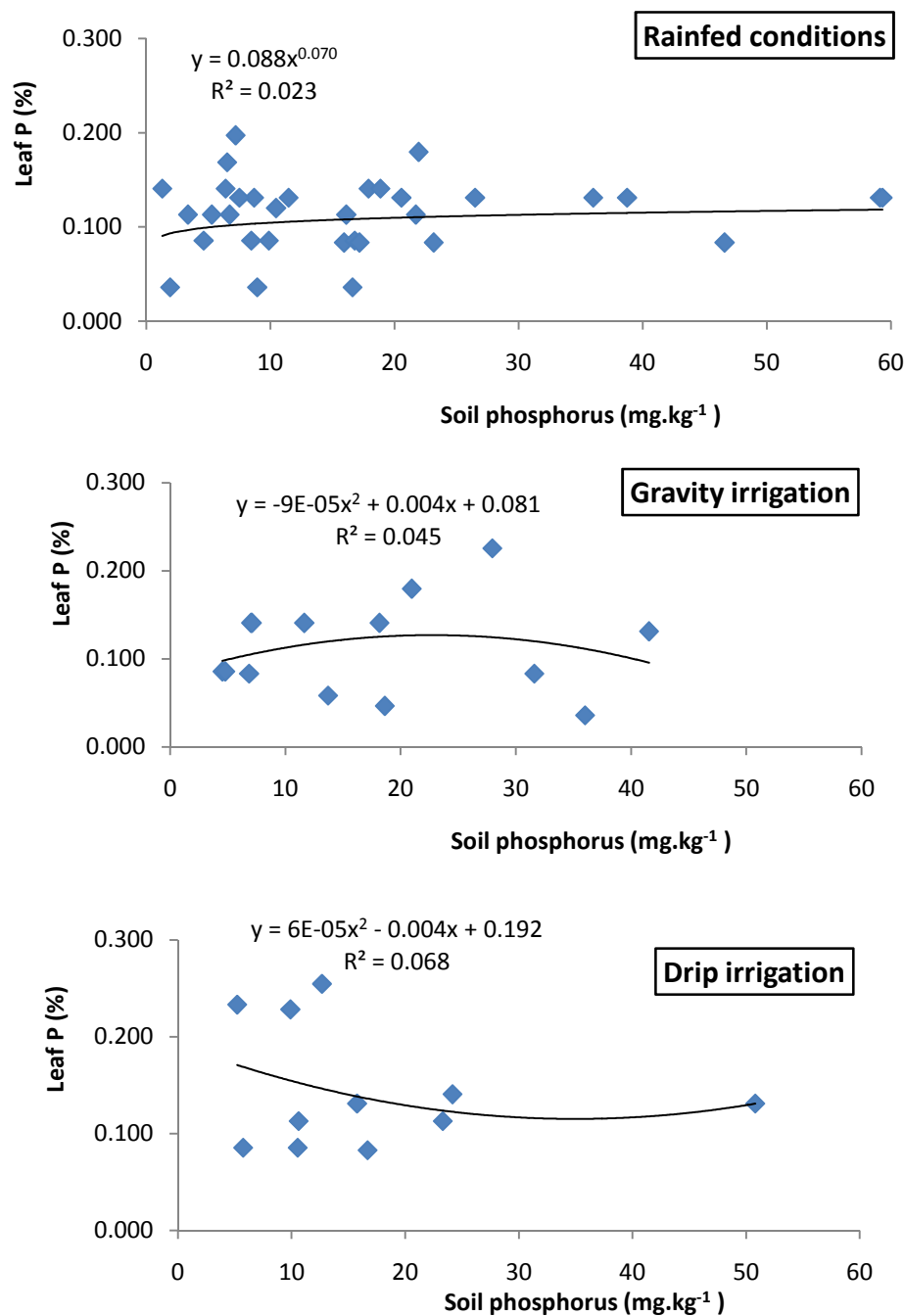
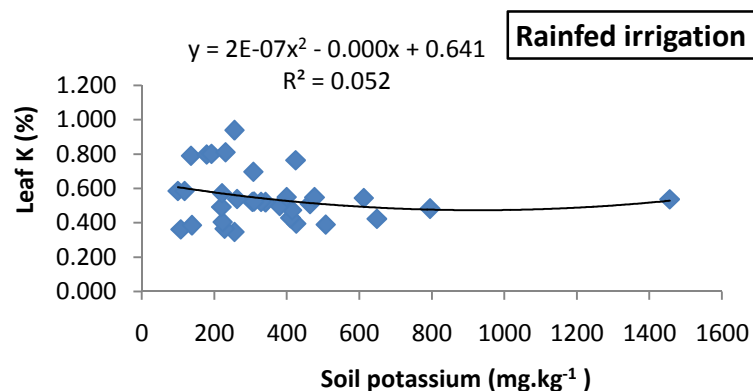
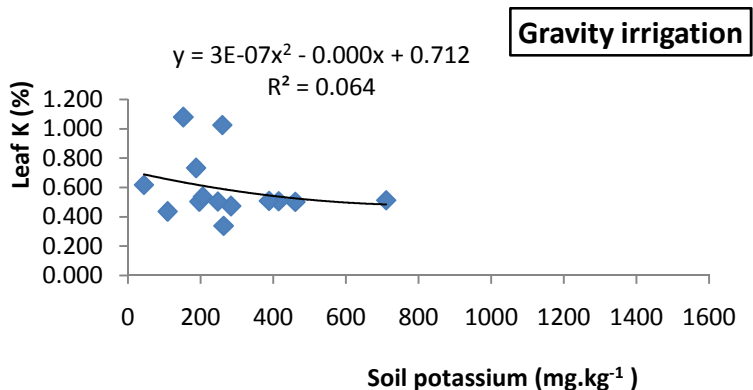


Figure6.Evolution of the leaf phosphoruscontent depending on the soil available phosphorus content (0-30cm) for the three driving modesof the studiedorchards.

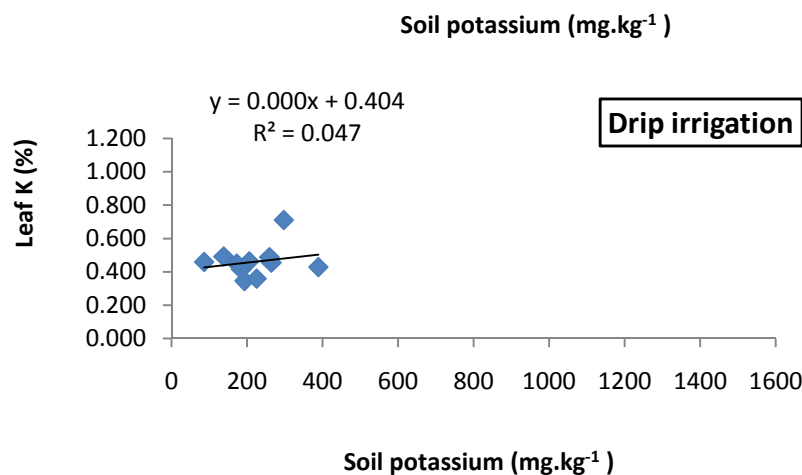
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199 **Figure7.Evolutionof the leaf potassium content depending on the soil exchangeable**
 200 **potassium content (0-30cm)for the three driving modesof the studiedorchards.**

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202 4. CONCLUSION

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204 This study has revealed shortcomings as regards fertilization practices of olive cultivation at
 205 Sais region. Indeed, approximately 48.3% of the farmers surveyed provide no fertilizer for
 206 their olive trees. The laboratory analyzes of soil and leaves samples collected in these
 207 orchards have confirmed these failures: Much of olive orchards require additions in
 208 fertilizers. The studyof the correlationbetween yield andsome soil parametersshowedno
 209 correlation between the olive yield and soil fertility parameters (soil nitrate or phosphorus or

exchangeable potassium contents). Also, the olive yield was not correlated with the leaf nitrogen or phosphorus or potassium contents. The relationship between the olive nutrition parameters (leaf nitrogen, phosphorus and potassium contents) and the soil fertility parameters (soil nitrate, available phosphorus and exchangeable potassium contents), at the 0-30 cm horizon in the olive groves showed that olive leaf parameters were not linked to those of soil fertility. However, much of the leaf nitrogen content (about half) has been explained by the soil nitrate content but only in irrigated orchards. This diagnostic work done at Sais region has identified problems concerning, especially, fertilization of olive trees. The determination of the olive tree fertilization standards is a necessary step for a rational management of fertilizers for the olive trees. These standards will be developed through field trials.

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