

Diagnosis of soil fertility and nutritional status and characterization of olive orchard in central Morocco

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) Characterization of olive orchard ii) Determining the soil fertility levels and the assessment of nutritional status of these olive orchards. Composite soil samples from two depths (0-30 cm and 30-60 cm) and composite leaf samples were collected during the December/January period. Surveys were conducted on these orchards to collect data for characterization and analysis of different fertilization modes adopted in relation to olive yield. More than half of the surveyed groves (57%) are conducted in rainfed conditions. 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 and between the olive yield and the olive leaf parameters. The relationship between the olive nutrition parameters and the soil fertility parameters, at the 0-30 cm horizon, 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.

Keywords: *Olea europaea*, Nitrogen, Phosphorus, Potassium, Soil, Leaves, Surveys.

1. INTRODUCTION

The general situation of the olive orchards productivity throughout the world seems to be unsatisfactory. Indeed, about 70% of the olive orchards are traditional and marginal with a medium to very low productivity due, in a significant degree, to the lack of appropriate orchard management [1]. Under-application of inputs may lead to unsatisfactory yields, under the potentiality of the orchard [2]. The new intensive orchards (about 30% of the total) present a suitable productivity but are often associated with higher environmental impacts [3, 4]. Olive growing sustainability in the Mediterranean region is highly dependent on sustainability of soil resource management practices [1]. However, there is almost no information on the overall effect of soil status on olive yield [5].

In Morocco, the olive tree is the main fruit species cultivated, with about 840 000 ha until 2011 [6], and a large proportion of its total area located in rainfed areas. Olive growing is an intensive agricultural activity which generates almost 100 000 permanent jobs [6]. The olive sector contributes up to 5% of upstream agricultural GDP and accounts for 15% of agricultural foodstuff exports. The annual production for 2014 was 100 000 tones of table olives and 120 000 tones of olive oil. Almost 75% of the olives produced in Morocco go for olive oil whereas table olive represents 25% of olive production [6]. Olive yields are still below the olive sector potential. Indeed, the weather, in the drought case, and weak technical management are the main factors generating the low productivity registered for olives. Fertilization is one of the techniques non mastered by the majority of Moroccan growers and which consequently leads to low yields of the olive tree. This work done at Sais region in Central Morocco, has as main objectives:

- Characterization of olive orchard at Sais region in central Morocco.
- Determining the soil fertility levels and the assessment of nutritional status of these olive orchards.

2. MATERIAL AND METHODS

2.1. Surveys

This study was conducted at Sais region, through surveys, soil testing and leaf analyzes. 58 olive orchards, distributed on the territory of the study area (Moulay Driss, Mhaya, Ain Jemaa, Dkhissa, Agourai, Ras Jerry, Oued Jdida, Ain Kerma, Ain Orma, Ain Chkef, Sfassif, Laksir, Sebt Jehjouh, Ait Ouallal) were chosen at random. A plug survey was developed and served as a support for data collection in the field. These relate to the culture 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 analyzes 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 [7] for nitrates, Olsen [8] for phosphorus, Walkley and Black [9] for organic matter, Drouineau [10] for active limestone extraction and ammonium acetate [11] 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 [12].

2.4. Statistical analysis

Correlation and regression analyzes between some parameters were performed using the software Genstat.

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).

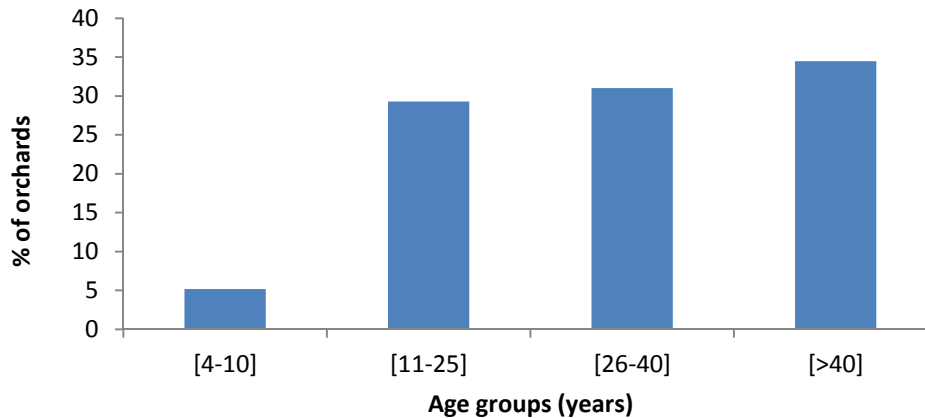


Figure 1. Olive orchards distribution according to their ages

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.

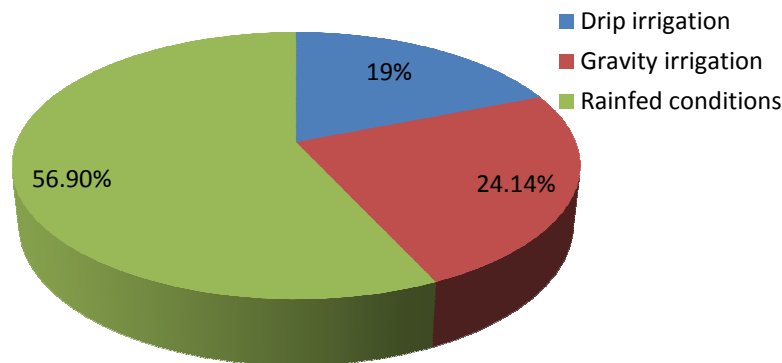


Figure 2. Olive orchards distribution according to the driving mode

3.1.3. Density

Most plantations (84.5%) have a planting density between 100 and 350 trees.ha^{-1} (Figure 3). Extensive densities ($<100 \text{ trees.ha}^{-1}$) represent only 5% of respondents orchards. The rest (10%) is represented by orchards with the density exceeds 350 trees.ha^{-1} .

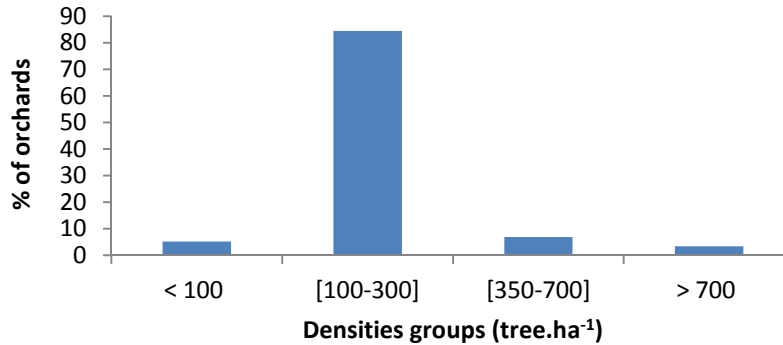


Figure 3. Olive orchards distribution according to their planting densities

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⁻¹. Olive trees under drip irrigation recorded an average yield of 5.1 t.ha⁻¹, those led by gravity irrigation recorded an average yield of 1.9 t.ha⁻¹. For orchards in rainfed conditions, the average yield is 1.8 t.ha⁻¹.

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%). The olive trees are reported to grow quite well on soils containing

125 more than 1% of organic matter [13], even if a threshold of 1.5% is considered low in other
126 conditions [14].

127 3.2.2. Active limestone content

128 The average content of active limestone was 12.5% and 10.9%, respectively, for the soil
129 layers 0-30 cm and 30-60 cm. It varied between 0 and 18% for the 0-30 cm horizon and 0 to
130 19.8% for the 30-60 cm horizon. Excellent yield and vegetative growth can be observed, in
131 both soils with small amount of limestone and where this amount reaches 50%, with a limit of
132 76% [15].

133 3.2.3. pH

134 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
135 horizon. Alkaline soils predominate in the olive orchards studied. Indeed, in the two soil
136 layers 0-30 and 30-60 cm, 96.6% and 93.1% of soils, respectively, are basic soils according
137 to standards set by [16] (Figure 4). It is well known that the olive-tree tolerates a wide margin
138 of soil pH, but the neutral, slightly alkaline values to alkaline ones, between 7 and 8.5,
139 assure its best development [17].

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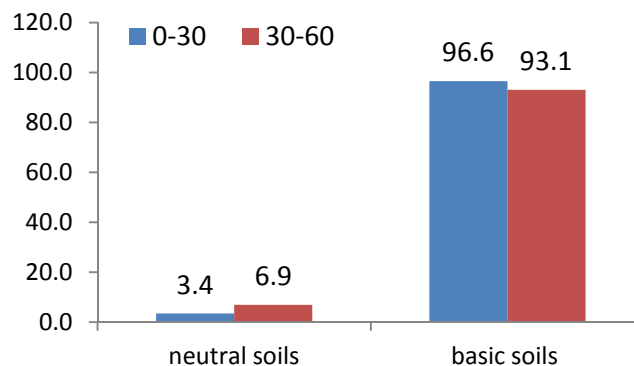


Figure 4. pH of soil sampled groves

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144 3.2.4. Soil fertility

145 For a given site, soil fertility levels have declined in the lower layers of the soil in comparison
146 to the topsoil [5]. In our study, the soil nitrate levels ranged between 1.8 and 71.4 mg.kg⁻¹
147 and between 1.5 and 40 mg.kg⁻¹, respectively, for the soil layers 0-30 cm and 30-60 cm. For
148 phosphorus, soils showed levels ranging from 1.3 to 59.3 mg.kg⁻¹ for the 0-30 cm layer and
149 from 1.4 to 41.7 mg.kg⁻¹ for the 30-60 cm layer. The soil potassium ranged between 43.8
150 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
151 cm horizon. The soil P and K levels are higher than the values found in other studies in
152 Tunisia, Syria and Spain. Indeed, in a soil fertility survey of olive trees in Sidi Bouzid
153 (northwest Tunisia), [18] reported values between 6 and 19.9 mg.kg⁻¹ to P (average of 11.8
154 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.
155 In Syria, [5] reported in the topsoil (0-20 cm), the P values ranging from 2.4 to 23.2 mg.kg⁻¹
156 and K values between 14 and 386 mg.kg⁻¹. [19] reported, in Andalusia, soil potassium
157 contents between 61 and 171 mg.kg⁻¹ in the 0-30 cm layer. Pa against, [20] found, in the
158 Andalusian olive, soil potassium contents between 105 and 565 mg.kg⁻¹ and soil phosphorus
159 contents between 60 and 162 mg.kg⁻¹ in the 0-30 cm layer .

160 3.3. Determination of the nutritional status of the olive orchards

161 The olive leaf analysis revealed low leaf nitrogen, phosphorus and potassium contents which
162 have varied, respectively from 0.224 to 0.602%; from 0.036 to 0.255 and from 0.338 to
163 1.078%. [18] found values between 0.058% and 0.14% for P and between 0.43% and 0.93%
164 for K. [5] 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 [21] and [22] (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). [5] 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.

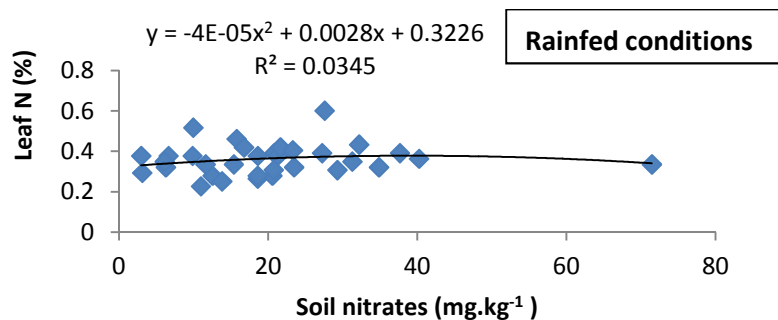
Yield	Rainfed conditions		Gravity irrigation		Drip irrigation	
	Model	R^2	Model	R^2	Model	R^2
Soil nitrates	$y = -0,0005x^2 + 0,0257x + 1,5725$	$R^2 = 0,0067$	$y = 2,96e-0,036x$	$R^2 = 0,3033$	$y = -0,0007x^2 - 0,0638x + 6,6668$	$R^2 = 0,076$
Soil phosphorus	$y = 0,0002x^2 - 0,0365x + 2,3283$	$R^2 =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

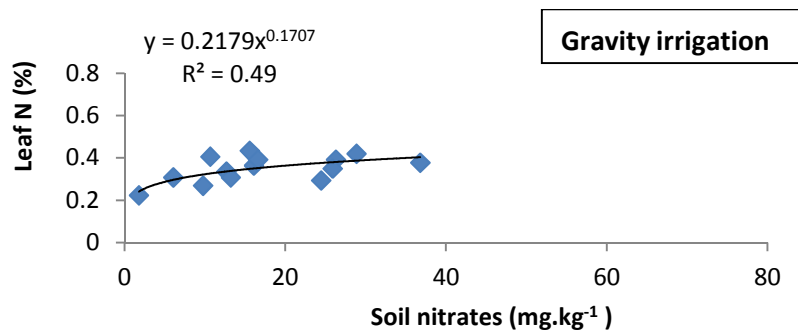
The olive yield is not correlated with the leaf nitrogen or phosphorus or potassium contents (Table 4). [5] found the same results for nitrogen and phosphorus when they noted a significant correlation between the olive yield and the leaf potassium contents with 26% of the explained variability. A strong negative correlation was observed by [23] between the olive yield and leaf phosphorus and potassium content.

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

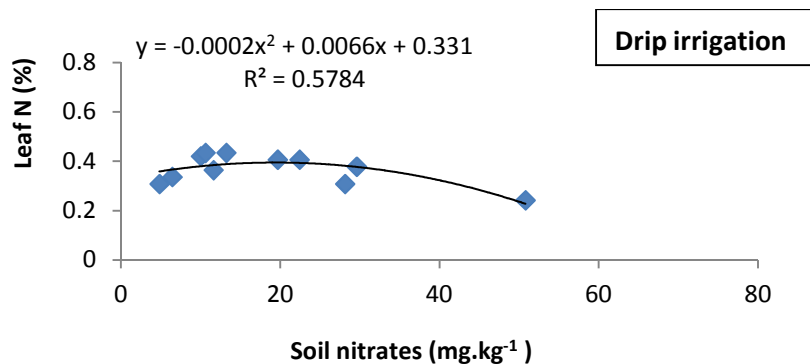
Yield	Rainfed conditions		Gravity irrigation		Drip irrigation	
	Model	R ²	Model	R ²	Model	R ²
% Leaf nitrogen	$y = -8,8455x^2 + 8,6368x - 0,1061$	R ² = 0,0045	$y = 184,75x^2 - 118,7x + 20,193$	R ² = 0,3515	$y = 166,6x^2 + 125,2x - 17,805$	R ² = 0,0299
% Leaf phosphorus	$y = 193,49x^2 - 38,882x + 3,4603$	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

193 We also studied the relationship between the olive leaf nitrogen, phosphorus and potassium
194 contents, at the 58 sampled orchards, and soil nitrate, available phosphorus and
195 exchangeable potassium contents, at the 0-30 cm horizon. Figures 5, 6 and 7 present
196 regressions curves produced between these parameters for each driving mode orchards
197 adopted by farmers (rainfed conditions, gravity irrigation and drip irrigation). These have
198 shown that nutrition parameters of olive leaves are not linked to those of soil fertility. With the
199 exception of nitrogen where much (about half) of the leaf content has been explained by the
200 soil nitrate content but only in irrigated orchards (Figure 5). Note that all these regressions
201 are not statistically significant. [18] also showed no relationship between the olive leaf
202 phosphorus and potassium content and the soil phosphorus and potassium content,
203 respectively.
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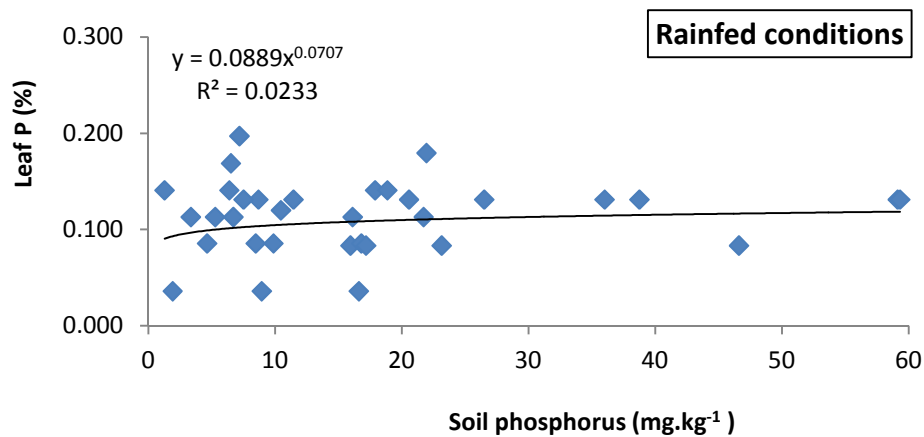


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210 **Figure 5. Evolution of the leaf nitrogen content according to the soil nitrate content (0-**
 211 **30 cm) for the three driving modes of the studied orchards.**

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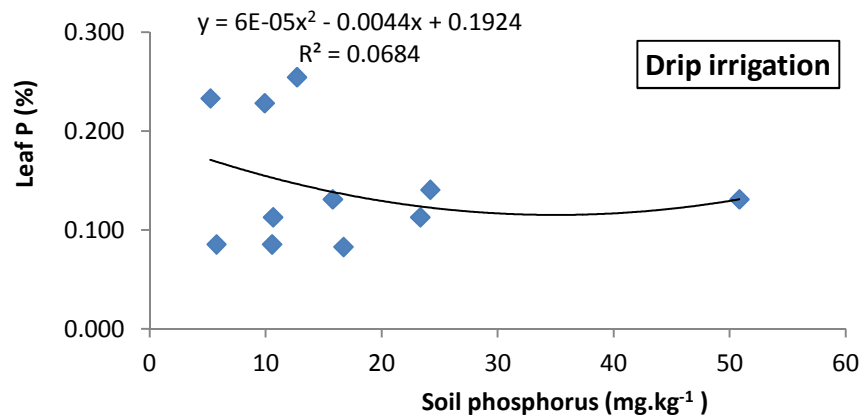
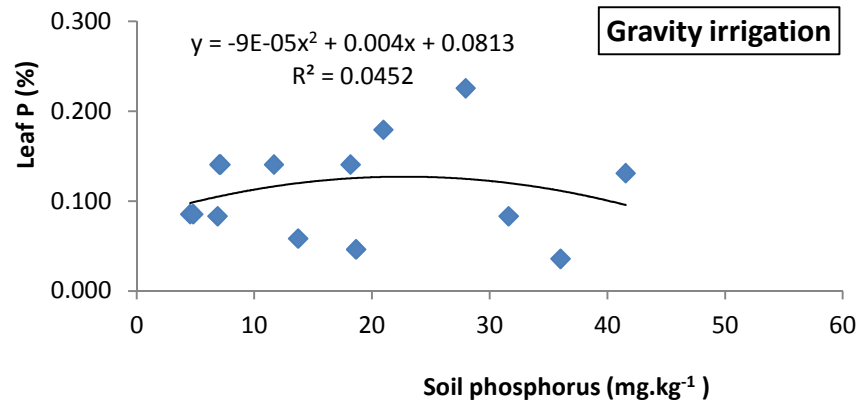
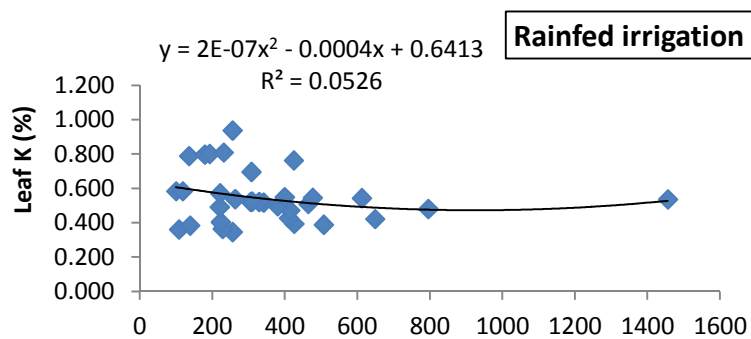
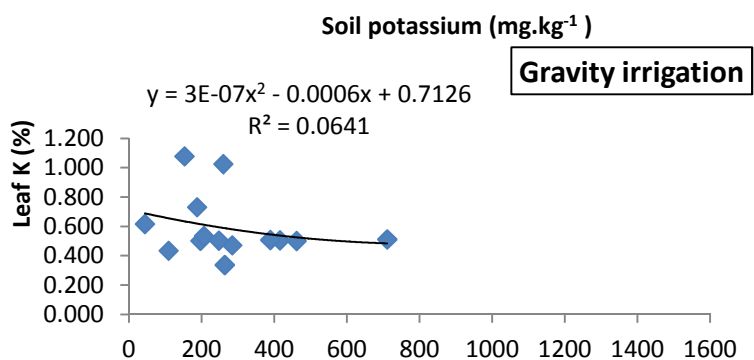


Figure 6. Evolution of the leaf phosphorus content depending on the soil available phosphorus content (0-30 cm) for the three driving modes of the studied orchards.

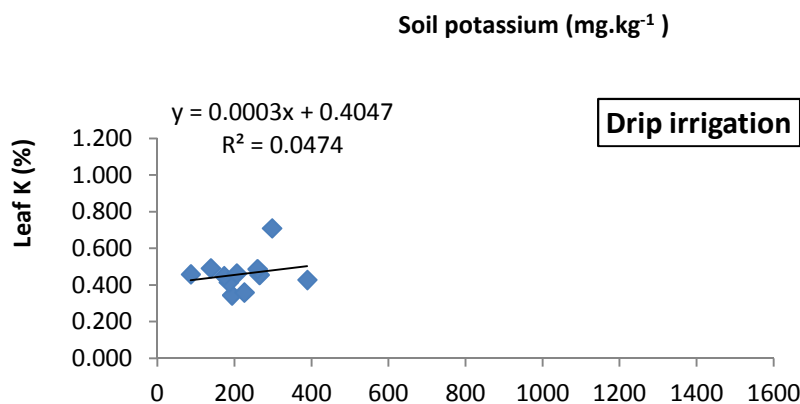
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Figure 7. Evolution of the leaf potassium content depending on the soil exchangeable potassium content (0-30 cm) for the three driving modes of the studied orchards.

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4. CONCLUSION

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- The surveys have revealed shortcomings as regards fertilization practices of olive cultivation at Sais region. Indeed, approximately 48.3% of the farmers surveyed provide no fertilizer for their olive trees.
- The laboratory analyzes of soil and leaves samples collected in these orchards have confirmed these failures: Much of olive orchards require additions in fertilizers.

- The study of the correlation between yield and some soil parameters showed no correlation between the olive yield and soil fertility parameters.
- 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 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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