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CHAPTER II

SOIL FERTILITY AND PLANT NUTRITION

RELATIONSHIP BETWEEN SOIL FERTILITY AND PHOSPHORUS AND POTASSIUM OLIVE PLANT NUTRITION

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Introduction

The Tunisian olive groves cover 1,620,000 ha (30% of arable land), which corresponds to more than 5.8 millions trees (COI, 2000). Olives grow on diverse soil and climate conditions. Furthermore, 15 millions of olive trees, covering 800,000 ha are planted with a density of 17 trees/ha. These plantations grow under lower semi-arid to arid climatic conditions on very poor soils (Braham, 1997). Cultivation of olives is the only remunerative agricultural activity available for the area.

Moreover, the farming is crucial for protecting the soil against desertification and land degradation. However, adaptation of the plants to these climate conditions is highly related to soil qualities. For example, in very permeable and deep soils, the olive trees can have a good production even under low precipitation (200 mm/year in Sfax).

Since regional guidelines for olive tree fertilisation are missing, norms established for different geographic zones and different farming methods were adapted in Tunisia. Therefore, the problem of regional normatives taking into consideration soil fertility and olive tree nutritive status are urgent for our country. Unfortunately, few research studies are dedicated to this theme so far. Thus, we tried to perform an analytical study on soils planted with two olive cultivars: Chetoui in the North and Chemlali in the Center.

The major aims of this study were to determine Tunisian soil types covered by olives, to analyse the nutritive status of olive groves and to establish Tunisian norms for interpretation of leaf and soil analysis. These norms will be established by looking for correlation between soil chemical wealth in labile P and K and the amounts of these elements in the plant.

Should be mentioned that the olive trees are characterised by yearly alternation, internal storage, and remobilization mechanisms. These phenomena are closely connected to several climatic factors determining the annual yield. There is great need in Tunisia to establish reliable norms of olive fertilisation, because adaptation of results from other countries may not be suitable for the climate and soil conditions of our country.

Materials and methods

The plant materials retained in this study derive from two cultivars of olive trees that are grown for oil production (*Olea europaea* L.), “Chetoui” and “Chemlali”. Chetoui cultivar with erected harbour is especially present in the North of Tunisia. Chemlali cultivar, vigorous with falling harbor covers the nearly all the olive plantations in the Centre and the South (Labaied, 1981).

These olive trees are productive and depending on parcels and regions, they are grown on both rainfed and irrigated conditions. Vase pruned they have a marked tendency towards the alternation. The extended area included in this study allows the investigation of olive orchards grown under different climatic floors (Table 1). Indeed the rainfall rate is decreasing from 450 mm/year (Tunis region) to 200 mm/year (Sfax region). This zone includes regions of Tunis, Sahel, Sidi Bouzid and Sfax (Table 2). The number of parcels was limited to 34 in order to take all leaves samples during flowering stage.

Table 1. Rainfall rate (mm/year) during 1995/96 and 1996/97

Region	95/96	96/97
Tunis Region	586.7	280.8
Sahel Region	732.1	182.2
Sfax Region	463.6	154.3
Sidi Bouzid Region	380.5	207.7

Table 2. Sampled parcels distribution according to regions

Region	Situation	Number of parcels
Tunis Region	North	11
Sahel Region	East-Center	7
Sfax Region	Center & South-East	7
Sidi Bouzid Region	West –Center	9

The choice of selected parcels was based on the following criteria:
- Well kept olive groves;
- Planted in conformity with overall region's management system; and
- Productive olive trees.

Soil samples have been taken using an auger at the tree foliage limit, from three depths (A: 0 to 30 cm, B: 30 to 60 cm and C: 60 to 90 cm). For each parcel samples were taken from several points distributed as “Z” form. Classic methods of analysis were used in this study. Soil samples were analysed at the Laboratory of Soil Science of the National Agronomic Institute of Tunis. The following parameters were determined: Particle size distribution, pH, Cation Exchange Capacity and organic matter, total and active calcareous, labile phosphorus (OLSEN) and labile potassium (ammonium acetate method) contents.

At the same time leaf samples were taken from each parcel. Bouat (1960) esteems that one-year leaves and twigs are most appropriate for sampling because these twigs will carry fruits. These twigs are present in several positions on the tree: in branch extension or laterally, in high or low position and inside or outside the tree.

On the other hand, all adult leaves, of the same age, present appreciably the same nutrient contents. Thus, one-year leaves were taken from twigs situated at the man height level and in the tree periphery. The sampling was made during flowering stage. This phenological stage is reached from April to June. After leaves mineralisation and mineral elements extraction, potassium and calcium amounts were measured by flame photometry; Fe, Zn and Mg leaf contents are determined by atomic absorption. Whereas, phosphorus amount was estimated by colour spectrophotometry.

Results and Discussions

Soil analysis

All of the 34 soil samples (Table 3) that are slightly alkaline with pH range between 7.5 and 8.5, are suitable for olive farming (Martinez, 1984; Loussert and Brousse, 1978; Chavez, 1975). However a gradient of soil texture was revealed from North to South. Indeed clay content decreases from the North to the South and increase from the surface to increasing depth. Most of parcels (55,88 %) have less than 15 % of clay in the arable layer.

In comparison with Troncoso and Gonzalez (1972) norms (best average between 15 and 25%) this amount is considered low. These soils are highly permeable (15 to 20 cm/h) and have a low water retention capacity (5 to 6 % of dry soil) therefore are suitable for olive trees grown in arid zones (Loussert and Brousse, 1978). For the horizons B (30 60 cm) and C (30 90 cm), 44% of parcels have clay content less than 15%.

The organic matter rates vary from 0.14 to 2.77 % for all samples. Moreover, the majority of studied soils have a low organic matter content: less than 1,2 %. The Cationic Exchange Capacity (CEC) is closely connected to clay and organic matter in the soil contents (Gargouri, 1998); this generates a relatively low CEC for the majority of samples. Almost-all samples have P_2O_5 (Olsen) content less than 45 ppm. Therefore, Tunisian olive soils are classified as deficient in P according to Mediterranean norms: 50 60 ppm of P_2O_5 (Recalde, 1975; Loussert and Brousse, 1978).

Concerning potassium, in the sandy soils the amount of labile potassium varies from 55 to 365 ppm, whereas in the clayey soils its value is between 70 to 715 ppm because in these soils potassium is less leached. Therefore for all the tested soils, labile potassium can be classified in the optimal range (30 to 400 ppm) proposed by several authors, (Recalde, 1975; Gonzalez and Troncoso, 1972; Pansiot and Rebour, 1960).

Table 3. Soil analysis

Region	Organic matter (%)			Clay (%)			Active calcareous (%)			P Olsen (ppm)			K labile (ppm)		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
							Tunis Region								
BA1	2.64	1.5	0.67	39.13	35.73	41.9	9.75	11	16.75	5.55	6.5	9	610	330	190
BA2	1.72	1.44	0.56	40.4	45.88	39.9	12.5	16	15	7.9	5.45	2.75	333	315	195
Be	1.95	0.95	0.35	23.33	30.53	27.35	6.75	10.5	12	10.15	5.95	5.35	335	198	133
Eh	2.64	2.05	0.95	27.75	30.13	30.7	10.75	10.25	5.75	6.7	8.6	9.9	385	315	225
INAT	2.25	1.24	0.6	33.6	41	38.05	18	20.5	21.25	8.15	10.55	27.8	470	208	125
INAT	1.47	1.27	0.71	38.86	40.48	39.70	19	11	23	11.8	14.5	12.2	260	205	115
Kh	2.15	1.69	0.7	33.45	36.6	17.77	19.5	20.5	23	11.75	5.9	6.8	143	183	140
Mor	1.69	1.21	0.53	35.95	45.45	30.32	9.5	12.25	15.5	6.9	3.4	4.75	255	108	88
Mor	1.96	1.4	0.56	32.9	24.4	36.9	7.25	8.75	12.5	9.8	4.35	5.35	245	200	170
SBA	2.77	2.05	0.88	22.75	28.18	36.3	13	12.25	15.5	15	20.5	15.7	715	533	483
ST	1.21	1.18	0.46	26.88	28.55	20.5	11.25	13	13.75	11.35	4.4	2.8	125	120	85
							Sahel Region								
En1	1.34	0.96	0.44	14.48	15.55	17.77	1	2.25	18.75	17.95	5.8	5.4	365	253	183
En2	0.62	0.59	0.31	4.63	8.3	16.5	0.5	0.5	3.25	20.3	6.5	4.2	55	73	180
En3	1.63	1.47	0.81	31.18	32.45	28.25	4.5	3	6.25	11.1	7.1	6.45	223	195	153
K1	1.11	0.66	0.64	9.4	7.35	8.15	1	1	12.75	13.55	6.25	6.35	143	110	123
K2	0.85	0.65	0.37	2.8	26.8	48.15	8	10.5	18.75	4.6	3.65	4.05	120	195	250
K3	1.47	0.88	0.44	21.63	20.55	26.27	5.75	6.5	11.25	7.75	5	5.65	175	85	105
Mo	1.18	0.82	0.2	20.78	15.58	13.35	2.75	4.5	11	6.55	5.5	3.75	153	105	80

(continued)

Region	Organic matter (%)			Clay (%)			Active calcareous (%)			P Olsen (ppm)			K labile (ppm)		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Sfax Region															
S1	0.69	0.72	0.47	9.35	12	11.75	3	3.5	10	8.1	4.8	4.4	128	128	100
S2	0.85	0.98	0.27	7.4	11.28	6.5	3	4.5	7.5	11.9	9.25	5.85	203	275	128
S3	0.93	0.53	0.4	13.45	5.03	8.6	4	1.5	3.75	11.7	5.35	5.4	170	65	83
S4	0.75	0.49	0.34	5	6.15	8.1	1.25	1.5	6.25	8.7	6.7	9	110	68	83
S5	0.86	0.79	0.41	7.13	19.53	9.45	3.75	3.75	7.5	8.45	4.35	5.8	93	70	88
S6	0.56	0.38	0.14	23.2	40.98	43.2	6	4.75	5.5	4.2	8.7	3.35	158	240	260
S7	0.65	0.66	0.27	12.88	12.98	18.15	3.5	2.5	6.5	7	4.5	5.25	103	103	113
Sidi Bouzid Region															
SB1	0.69	0.75	0.3	1.5	12.98	14.62	4.75	10	9.75	6	6.3	4.95	190	110	113
SB2	0.88	0.52	0.3	7.95	10.35	12.65	2.25	5	9.25	10.4	6.25	4.8	113	90	83
SB3	0.69	0.69	0.34	6.08	8.5	3.03	1.75	3.75	6.75	8.5	11.15	4.2	90	75	75
SB4	0.88	0.69	0.27	8.8	7.05	10.22	2.5	2.5	11.75	9.4	6.35	6.3	110	118	158
SB5	0.88	0.52	0.2	7.28	7.85	10.15	2.5	2.75	11.5	9.25	6.75	8.1	110	100	130
SB6	1.17	0.56	0.71	0.98	9.23	16.92	2.5	6	16.5	8	6.2	14	270	115	78
SB7	0.82	0.59	0.3	5.78	19.88	9.92	3.75	6	13.75	18.7	5.8	7.15	105	95	83
SB8	1.06	0.53	0.14	5.78	6.43	6.92	2.5	2.75	10.25	19.85	6	7.1	93	73	75
SB9	0.72	0.53	0.28	8.75	6.88	10.8	1.5	6	13.25	16.3	6.5	7.05	118	90	66

En: Enfidha; K: Kondar; Mo: Monastir; S: Sfax; SB: Sidi Bouzid; BA: Borj El Amri; Kh: Khlidia; Eh: Ennahli; SBA: Sabelet Ben Ammar; ST: Sidi Thabet; Be: Bejaoua; Mor: Mornag

Leave analysis

Leave phosphorus contents (Table 4) vary from 0.058% to 0.139%. According to Mediterranean norms (Recalde, 1975) the absolute deficiency limit in P is 0.085% of dry matter. Therefore 58.9 % of the studied samples are below this limit. Concerning leaf potassium content, three classes are considered: for the first one K is lower than 0.3 % (deficiency according to Mediterranean norms), for the second, it varies between 0.3 % and 0.74 % and for the third, K leaf content is more than 0.74 %. The studied samples were divided between the two last classes. The second class contains 73.5 % of samples with a minimum of 0.43% of dry matter. The third class regroups 26.5 % of samples with maximum potassium content of 0.93 % of dry matter. Since the critical level proposed by Recalde (1975) is 0.30 %, one can conclude that there is no potassium deficiency in the studied samples.

Table 4. Leaves analysis

Leaf content	Tunis region											Sahel region					
	BA1	BA2	Be	Eh	INAT	INAT	Kh	Mor	Mor	SBA	ST	En1	En2	En3	K1	K2	K3
P %MS	0.08	0.11	0.06	0.07	0.10	0.10	0.07	0.12	0.08	0.08	0.06	0.09	0.10	0.14	0.08	0.14	0.09
K %MS	0.46	0.50	0.61	0.93	0.87	0.73	0.46	0.78	0.45	0.72	0.55	0.77	0.79	0.71	0.72	0.79	0.65
	Sahel	Sfax region							Sidi Bouzid region								
	Mo	S1	S2	S3	S4	S5	S6	S7	SB1	SB2	SB3	SB4	SB5	SB6	SB7	SB8	SB9
P %MS	0.07	0.06	0.10	0.06	0.07	0.06	0.10	0.11	0.08	0.07	0.07	0.08	0.08	0.07	0.08	0.07	0.10
K %MS	0.58	0.74	0.78	0.73	0.54	0.47	0.58	0.53	0.57	0.54	0.54	0.43	0.45	0.51	0.49	0.66	0.75

En: Enfidha; K: Kondar; Mo: Monastir; S: Sfax; SB: Sidi Bouzid; BA: Borj El Amri; Kh: Khlidia; Eh: Ennahli; SBA: Sabelet Ben Ammar; ST: Sidi Thabet; Be: Bejaoua; Mor: Mornag

Correlation between studied parameters

We have considered the contents of labile phosphorus and potassium in three soil layers in order to look for critical content indicating mineral deficiency in plant nutrition. However, no relationship between phosphorus in leaves and labile phosphorus in soil was found (Fig. 1). It seems that for all the studied samples, P concentrations are located in suitable range.

On the other hand, minimum P leaves content which is 0.058 % corresponds to labile phosphorus value of 4.35 ppm. Similarly, there is no correlation between potassium leaves content and the labile potassium in soil. However when the evolution of potassium leaves content was related to the labile potassium in soil (Fig. 2), we notice that for a minimal value of potassium leaf content of 0.43% corresponds a labile K of 80 ppm. For clayey soils, the minimal value of labile potassium is 110 ppm (Fig. 3).

According to these results, for phosphorus we propose for rainfed olive orchards: the suitable level of exchangeable P in soil is 8 ppm and for P leaf content is 0.07 % of dry matter according to Braham and Mhiri (1997). In respect to labile potassium, suitable levels are 80 ppm (clay <15 %) or 150 ppm (clay > 15%). Finally, the suitable level for K leaf content is 0.5% of dry matter.

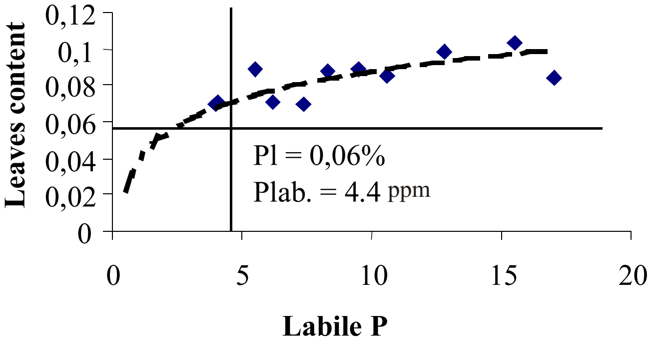
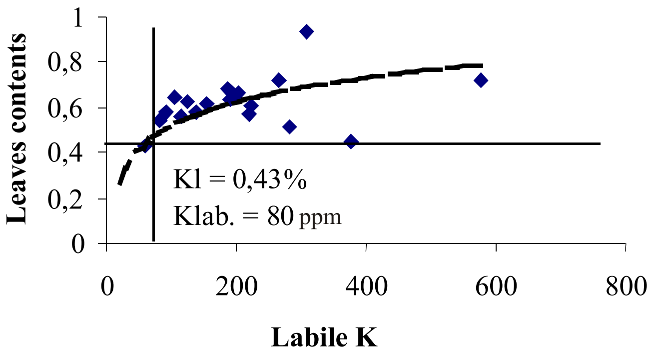


Figure 1. Evolution of P leaf content according to labile P

Figure 2. Evolution of K leaf content according to labile K



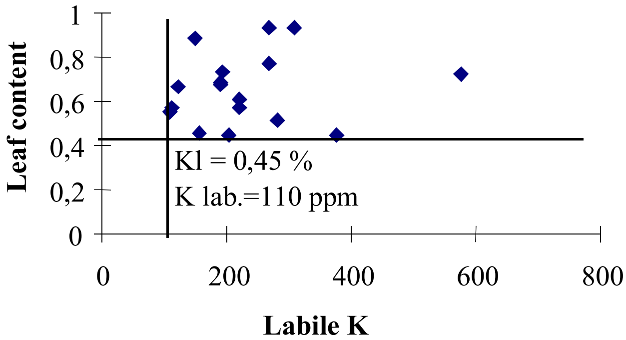


Figure 3. Evolution of K leaf content according to labile K in clayey soils

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