Diagnosis of the Nutritional Status of Rainfed Olive Orchards

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Foliar analysis is used to confirm the nutritional constraints in rainfed olive yields in Tunisia that are caused by inadequate and improper nutrient management.

Tunisia is one of the most important olive-growing countries of the southern Mediterranean region. Despite the crop's importance, the main constraints facing Tunisian olive production are low productivity, aging trees, and inadequate nutrient management. The nutritional deficit in these orchards has resulted in crop losses, low fruit quality, and in severe cases, the death of trees. Generally, fertilization is done without any previous knowledge of the nutritional status of the trees or the soil nutrient balance. Excessively negative, or positive, nutrient balances are hampering the sustainability of olive crop productivity and orchard soil fertility in Tunisia.

Nutrient application should meet, and not exceed, the seasonal demands of the orchard. It is important to understand the nutritional status of olive trees and their real nutrient demand to get fertilizer application right. In rainfed orchards, farmers often limit their application of fertilizers because of the risks of low rainfall, the high cost of fertilizers, and a general lack of knowledge concerning the importance of adequate fertilization.

Table 1. Description of on-farm experimental olive sites in northern Tunisia.

Farm	Area, ha	Tree age, yr.	Planting density, tree/ha	Yield, kg/tree 2014	Yield, kg/tree 2015	Nutrient input[1], kg/tree
1	20	62	100	7.0	35	3
2	4	40	100	6.0	28	3-4
3	0.5	55	100	10.5	39	30

[1] Common farm practice of applying 3 to 4 kg ammonium nitrate/tree in February. Farm 3 received 30 kg cattle manure/tree.
Cumulative rainfalls were 545 mm in 2014 and 533 mm in 2015. Olive tree density was 100 trees/ha (10 x 10 m spacing) planted with Chétoui and Jarboui varieties.

Table 2. Soil analysis of the three on-farm olive orchards sites in Teboursouk, Tunisia.

Farm	Depth, cm	Organic matter, %	Total $CaCO_3$, %	pH	Available K, ppm	Available Ca, ppm	Available P, ppm
1	0-30	1.7	48	8.5	231	9,670	46
	30-60	1.7	46	8.5	208	9,250	38
2	0-30	1.0	56	8.7	295	8,970	87
	30-60	0.9	53	8.5	262	8,130	75
3	0-30	0.9	47	8.1	290	8,650	85
	30-60	0.9	47	8.3	271	9,340	87

On-farm experiments were conducted during 2014 and 2015 in three rainfed orchards located in the north-western province of Teboursouk. The olive orchards were 40 to 60 years old, which represents the average for the region. The average fruit yield was low (1,000 kg/ha) in 2014 and was considered an "off" year. In 2015, an "on" year, yield exceeded 2,800 kg/ha. Besides wanting to highlight the NPK balance and the role that best nutrient management practices can play, researchers also wanted to determine if nutrient management can help to reduce the yield swings that result from olive's typical alternating (on/off) fruit-bearing years.

For foliar diagnosis, leaf samples were collected from each experimental site in July for both years. In each farm, two bulk leaf samples were collected, each leaf sample comprised of 150 healthy, fully expanded mature leaves collected from the middle portion of non-bearing current season shoots. Leaves were analyzed for N, P, and K. The olive orchards were fertilized by one broadcast application of 3 to 4 kg AN/tree in February (common farm practice) in both years of experimentation, except for farm 3 where 30 kg cattle manure/tree was applied (**Table 1**).

The soil was clay loam texture, characterized by 46 to 57% total $CaCO_3$, 0.9 to 1.7% organic matter, and pH (water) of 8.1 to 8.7. Soil available K (ammonium acetate extractable) varied between 230 and 294 ppm, available Ca between 8,650 and 9,670 ppm, and available P (Olsen) varied between 46 and 85 ppm (**Table 2**). There was no significant difference between surface (0 to 30 cm) and sub-surface (30 to 60 cm) sampling for all the analyzed parameters.

The olive tree tolerates a wide range of soil pH, but a neutral to slightly alkaline (7 to 8.5) pH is most suitable. Organic matter and $CaCO_3$ content of the soils were adequate for proper growth of trees. Olive trees need at least 1% soil organic matter (Soyergin et al., 2002) and can tolerate a wide range of lime content in the soil up to very high values of 76% (FAO, 2006).

The available P contents in the soil of the three farms showed moderate variation. The minimum value was 38 ppm, above the critical level of 8 ppm proposed by Gargouri and Mhiri (2002). The soil available K was moderate considering the soil texture (clay loam soil). Based on the soil analysis, soils of the on-farm experimental sites were suited for olive tree cultivation.

Foliar Analysis

Foliar analysis showed that 50% and 67% of olive orchards were deficient in N in the 2014 "off" year and 2015 "on" year, respectively. A generally inadequate approach to N fertilization was considered the root cause of this N deficiency. The common practice of using a single application of ammonium

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; AN = ammonium nitrate; $CaCO_3$ = calcium carbonate. IPNI Project TUN-1

Table 3. Foliar N, P, and K analysis of olive tree varieties growing at three olive farms in Teboursouk, Tunisia.

			---- Farm 1 ----		---- Farm 2 ----		---- Farm 3 ----		---- Average ----	
		Threshold values[2], %	Chétoui	Jerboui	Chétoui	Jerboui	Chétoui	Jerboui	Chétoui	Jerboui
Nutrient	Year		----------	----------	----------	---------- %	----------	----------	----------	----------
N	2014[1]	1.5 to 2	1.67 a[3]	1.41 a	1.45 b	1.59 a	1.70 a	1.37 a	1.61 a	1.46 a
	2015		1.37 b	1.40 a	1.77 a	1.37 b	1.59 b	1.42 a	1.58 b	1.40 b
P	2014	0.1 to 0.3	0.10 a	0.13 a	0.11 a	0.13 a	0.11 a	0.13 a	0.11 a	0.13 a
	2015		0.11 a	0.09 b	0.08 b	0.09 b	0.08 b	0.09 b	0.09 b	0.09 b
K	2014	0.8 to 1	0.91 a	0.76 a	0.92 a	0.99 a	1.04 a	0.77 a	0.96 a	0.84 a
	2015		0.66 b	0.58 b	0.49 b	0.61 b	0.38 b	0.54 b	0.51 b	0.58 b

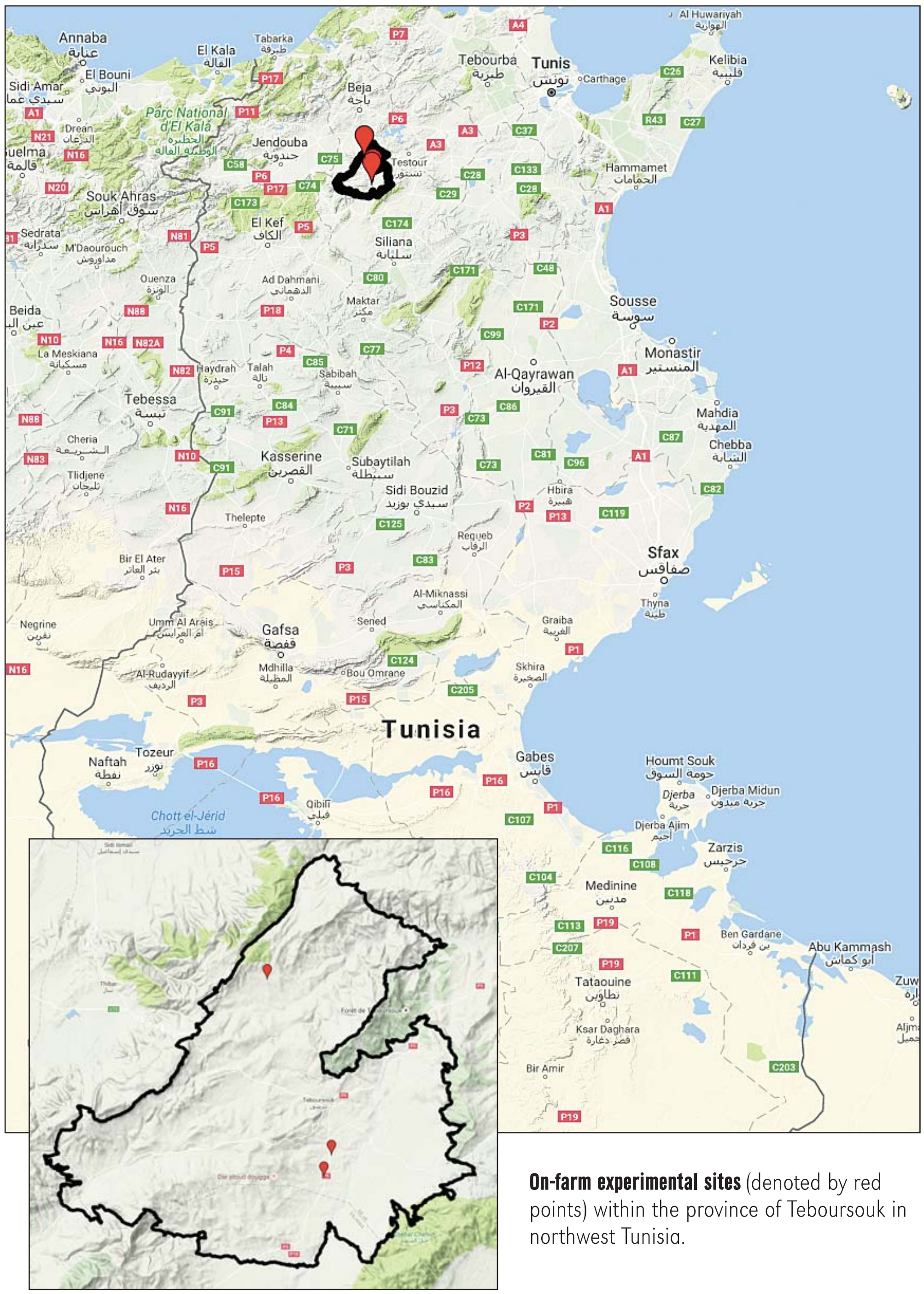
[1]2014 = "off" fruit-bearing year while 2015 = "on" fruit-bearing year.
[2]Pastor et al. (2005)
[3]For each nutrient, values followed by different letters in the same column differ significantly at $p < 0.05$.

nitrate each year leaves the fertilizer highly susceptible to loss, largely through leaching away from the root zone. The higher yield (over 30 kg/tree) observed in 2015 increased the extent of N deficiency, due to higher N uptake by the trees and the absence of any split application of N (**Table 3**).

For P, no deficiency was observed in 2014. However, leaf P concentrations decreased during 2015 below the published critical value of 0.1%. The low P concentration in 2015 can be attributed to high yielding trees, a corresponding high extraction of P by fruits, and also to the calcareous nature of these orchard soils that regularly precipitate P (Hidalgo et al., 2011). The conventional soil application of P is usually not very efficient (Ferreira et al., 1986) and foliar application remains the best alternative to correct P deficiency.

Similar to P, leaf K concentration also decreased in 2015. Although this is mainly due to the high fruit yield in 2015, the fall in leaf K concentration can be explained by redistribution of K from the leaves to the fruit during the period between July until December/January (harvest period). Furthermore, the high content of $CaCO_3$ and the soil texture (22 to 30% of clay) with high adsorptive power can affect soil K availability for olive trees (Hidalgo et al., 2011).

According to the threshold values in **Table 3**, three cases of N deficiency, zero cases of P deficiency, and two cases of K deficiency were found from the six samples taken during 2014. However, 2015 found



On-farm experimental sites (denoted by red points) within the province of Teboursouk in northwest Tunisia.

Symptoms of N (top), P (middle) and K (bottom) deficiency in rainfed olive orchards, Teboursouk, Tunisia.

Table 4. Nitrogen, P, and K leaf concentration range (% dry matter, var. Chétoui) in three olive farms, January 2016, Teboursouk, Tunisia.

Nutrient, %	July 2015	Jan 2016
N	1.37 to 1.77	1.26 to 1.31
P	0.08 to 0.11	0.04 to 0.06
K	0.38 to 0.66	0.34 to 0.38

four cases of N deficiency, five cases of P deficiency, and six cases of K deficiency.

In January 2016, a foliar diagnosis was done for subplots planted to the Chétoui variety (**Table 4**). Results showed moderate N deficiency and severe P and K deficiency as the range of leaf nutrient concentrations decreased from the July 2015 values. These foliar analyses confirmed the nutrient deficiencies observed.

Summary

In rainfed areas of Tunisia, low fertilizer use by olive farmers, mainly during the high fruit-bearing year, contributes to severe N, P, and K deficiency. The use of foliar P and K fertilization remains essential to overcome constraints related to P precipitation in highly calcareous soil or poor fertilizer solubilization under rain water scarcity. BC

Acknowledgments

This study was supported by International Plant Nutrition Institute.

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