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IV Effects of potassium foliar spray on olive, peach and plum, Part 1: olive experiments

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Introduction

The fruit tree industry is one of the most important agricultural sectors in Tunisia, with more than 2 million hectares planted mainly with olive (1.5 million ha), almond (257,000 ha), pistachio (44,000 ha) and palm date (26,000 ha). Citrus and stone fruits are also economically important crops (Table 1). Owing to water scarcity, the sector is characterized by significant disparities between regions and growers. For example, olive tree orchards have been found to vary from very low density (17 trees/ ha in the center and south of the country) to very high density with more than 1,250 t/ha, the difference depending mainly on water availability for irrigation. Water scarcity is the main limiting factor for Tunisian agriculture.

Mineral nutrition is one of the major tools to optimize fruit yield and quality (Tagliavini and Marangoni, 2002). Potassium is known not only to play an important role on olive yield and quality but also on water-use efficiency (Arquero *et al.*, 2006), which indicates its importance for the Tunisian fruit sector where trees have been traditionally grown on calcareous soils under rainfed conditions.

Nutrient uptake depends on nutrient supply to the root system i.e. nutrient availability and the nutrient requirement level and the uptake period (Chapin, 1991). Fine textured soils are characteristically K^+ fixing soils, where soil-surface application is almost without effect (Mengel, 2002). Fertigation relative to broadcast application has been shown to increase K mobility in the soil (Nielsen *et al*. 1999; Uriu *et al*. 1980; Southwick *et al*. 1996). Weinbaum *et al*. (1994) suggested that this effect of K fertigation in significantly improving K uptake resulted from increasing rhizosphere soil solution K concentration. However, limitation in tree capacity to take up K during the high demand period can present a problem (Weinbaum *et al*. 2002) especially in K^+ fixing soils.

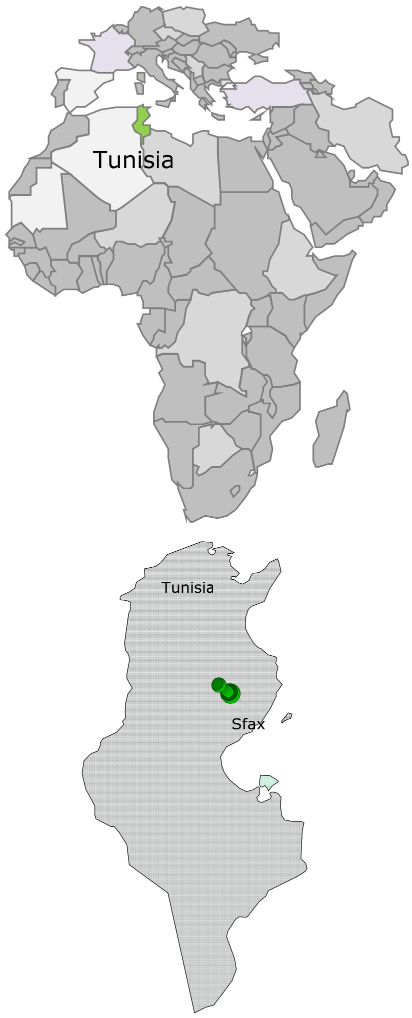
Dr. Mehdi Ben Mimoun at the experimental site, Sfax. Photo by M. Marchand.

Table 1. Fruit and nut production area and productivity in Tunisia (2006).

Fruit tree crop	Area	Yield
	ha	*'000 mt*
Olive	1,560,000	850
Almond	257,000	56
Pistachio	44,000	1.6
Date	32,600	131
Apple	25,500	120
Grape	25,000	54
Peach	23,000	73
Fig	23,000	30
Citrus	18,000	247
Pomegranate	13,000	70
Apricot	11,600	28
Pear	11,000	65
Plums	6,500	15

Foliar application of nutrients is in general helpful to satisfy plant requirement and has a high efficiency (Inglese *et al*. 2002). Potassium is particularly well adapted to this form of fertilization because soon after foliar spraying takes place it is rapidly translocated from the leaves (Mengel, 2002). Foliar application is thus an attractive means of K application to trees especially in arid zones where a lack of water under low rainfall conditions in summer drastically depresses absorption of soil nutrients.

In 2003, IPI coordinating research in the WANA region working jointly with the Fruit Tree laboratory of the Institut National Agronomique de Tunisie (INAT) began a project to evaluate the effect of potassium foliar spraying on different fruit crops (olive, citrus, pistachio, peach and plums) under different growing conditions.



Maps of the region and Tunisia showing the experimental area.

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The purpose of this paper is to present results obtained from the olive experiment under rainfed conditions. Results from fertigated orchards of peach and plum will be reported in another publication.

Materials and methods

This experiment was carried out over a period of five years beginning 2003 on a fine sandy soil at the Olive Institute experimental station which is located 26 km north of Sfax in the center of Tunisia. The zone is characterized by a semi-arid climate with an annual precipitation of 200 mm. A commercial olive orchard growing the cultivar Chemlali (the most important olive oil cultivar in Tunisia) was used for this experiment. The trees 24 x 24 m apart were grown using standard cultural practices of the Sfax region, i.e. under rainfall condition and without any fertilization.

At the beginning of the season, an estimate of potassium requirement was made based on the removal of nutrients contained in the yield (200 kg/tree) and the pruned wood. The total tree removal was estimated as 26.71 kg K_2O/ha (1.57 kg K_2O/tree). Potassium was applied by two different methods and on two quantities as indicated in Table 2. The same procedure was carried out annually from 2003-2007.

Potassium was applied as potassium sulfate (K_2SO_4).

The soil spreading treatments were carried out by one application made during the period of flower bud swelling.

Table 2. The different potassium treatments.

Treatments	Method	Quantity of K	Relative quantity
		kg K_2O/ha	
Control		0	
F50	Foliar spray	13	50% of tree removal
F100	Foliar spray	27	100% of tree removal
S100	Soil spreading	27	100% of tree removal
S200	Soil spreading	54	200% of tree removal

The foliar fertilization treatments were applied using a 100 liter/tree spray, with K concentration of a maximum of three per cent as follows:

- 30% of K total tree removal during the flower bud swelling
- 40% of K total tree removal during the second fruit development stage
- 30% of K total tree removal just at the beginning of the fruit color change.

Four single tree replications were used for each treatment. The vegetative growth of the shoots was measured once a month. Every 15 days after fruit set, fruit weight was measured on a sample of 200 fruits (50 per tree). At harvest yield per tree was determined and the oil extracted using an oil mill on four samples of 2.5 kg olives per treatment.

Leaf samples were collected in July each year from all treatments. About 40 fully expanded mature leaves per each tree were collected. In all cases, leaves were taken from the middle portion of the current season's terminal shoot growth. Leaf samples of the same treatment from each block were combined as samples of 100–120 leaves for determining leaf K concentration.

Results and discussion

Vegetative growth

No significant effect of the different potassium fertilization treatment was observed on vegetative growth (Fig. 1).

Fruit maturity and quality

The pattern of fruit growth was also not influenced by fertilization treatment (Fig. 2). Although fruit growth was higher during stage three for the 100 per cent foliar treatment, this increase was not statistically significant. Similar results were observed by Inglese *et al.* (2002).

Leaf Analysis

For each of the four years of the experiment the leaf concentration of K was higher for foliar treatments at F100 than the control (Fig. 3). However, the K concentration varied between "on"

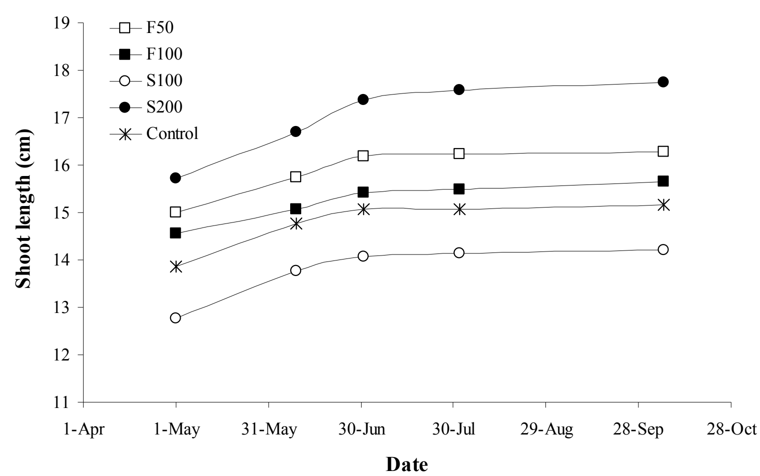

Fig. 1. The shoot growth (cm) for the different potassium fertilization treatments in 2003.

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and "off" years for all the treatments: the values were higher during the off year and were above the sufficiency threshold of 0.8 per cent for olive (Freeman *et al*., 1994) and vice versa. Fernandez-Escobar *et al.* (1999) observed the same results. These workers concluded that the high leaf K accumulation following the "off" year and the rapid decline after March of the "on" year suggest a large K demand by the reproductive structures of olive.

Yield and quality

After five years of experiments, potassium applied either as foliar or in the soil increased yields of olives. A significant difference in the cumulated yield was observed between foliar spray at 100 per cent nutrient replacement for K removal (F100) and the control (Table 3). The increase in yield is higher than 200 kg/tree, representing an almost additional yearly harvest yield for this very alternating cultivar. In other work, Restrepo-Diaz *et al*. (2008) did not observe any effect of potassium foliar fertilization on olive under rainfed conditions. However they stopped their experiments after only three years.

We assume that since F100 was applied in a split application (three times as compared to only one application to the soil) and the fact that the foliar applied K was more available to the tree, that these advantages contributed to the significant yield increase resulting from this form of application.

Potassium application to the soil and in foliar form significantly increased fruit weight and Flesh to Pit Ratio (Table 4). Foliar application of K (F100) proved to be best treatment with an increase of approx. 33 per cent in fruit weight and 24 per cent in Flesh to Pit Ratio, over the control. This beneficial effect may possibly have arisen as a consequence of a higher availability of assimilates.

At the same time, potassium application significantly decreased oil content in the fruit. As the oil content is negatively correlated with fruit weight and yield, we assume that the decrease in the oil

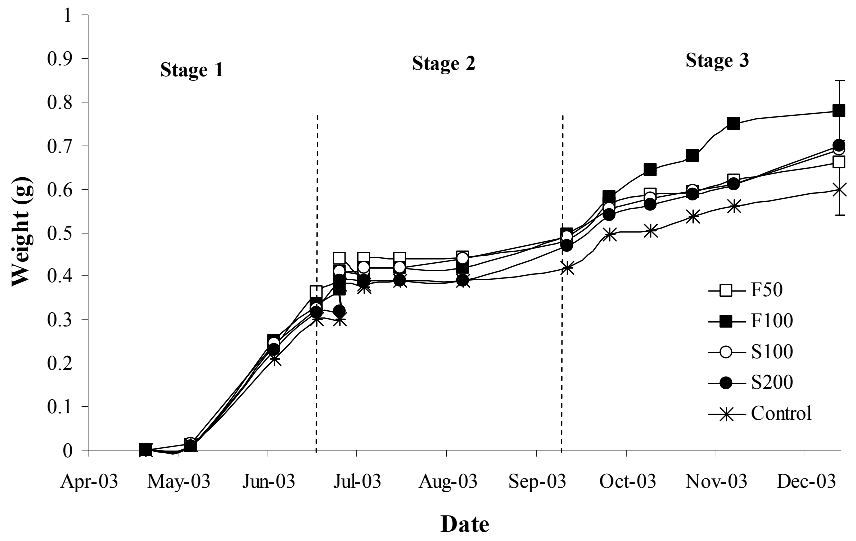

Fig. 2. The fruit growth (g, single fruit basis) for the different potassium fertilization treatments in 2003.

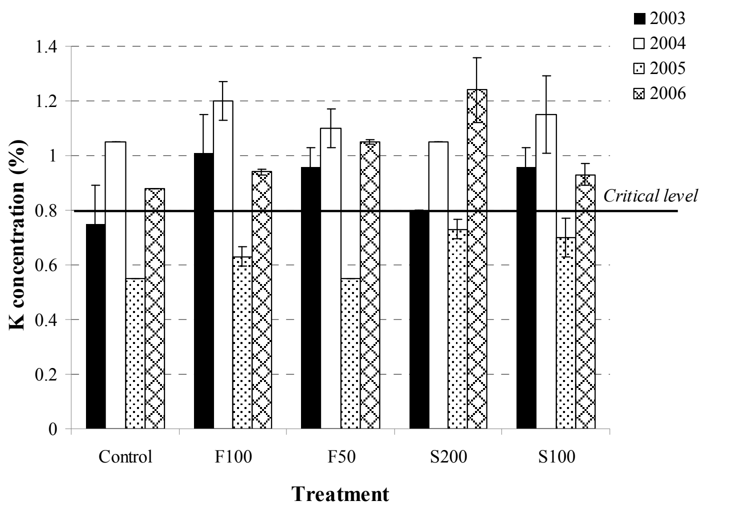

Fig. 3. The effect of fertilization treatments on K leaf concentration of Chemlali olive cultivar for the years 2003, 2004, 2005 and 2006. Bars represent SE.

Table 3. Average and cumulated yield in kg/tree during the period between 2003 and 2007. Different letters indicated statistical differences among means by Duncan's Multiple Range Test (p≤0.05).

Treatments	K application	Average yield					Cumulated yield
		2003	2004	2005	2006	2007	
	kg K_2O/ha	*kg/tree*					*kg/ha*
Control	0	143.75 a	0.00	34.25 a	56.25 a	84.8 a	5,423 a
F50	13	161.25 a	0.00	47.50 a	48.75 a	200.5 ab	7,786 ab
F100	27	183.25 a	0.00	71.25 b	36.25 a	237.0 b	8,972 b
S100	27	145.25 a	0.00	45.00 a	38.75 a	112.0 ab	5,797 a
S200	54	156.25 a	0.00	71.25 b	42.50 a	109.0 ab	6,443 ab

Note: Chemlali olive cultivar is an important alternate bearing cultivar with no yield after a good year which explains the absence of yield in 2004 after the excellent 2003 yield.

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content is due to dilution caused by the higher yields.

Fig. 4 shows the oil yield achieved in the different treatments (i.e. the product of yield and oil content). Clearly, the treatment of F100 (foliar application of potash at a rate to fully compensate for the removal of K in crop and buds) yielded approx. 50 per cent more oil than the control, thus offering the farmers a significant additional income.

Table 4. The effect of different potassium treatments on fruit pomological characteristics in 2003. Different letters indicated statistical differences among means by Duncan's Multiple Range Test (p≤0.05).

Treatments	K application	Fruit Weight	Flesh to Pit ratio	Oil content
	kg K_2O/ha	*g*		*%*
Control	0	0.61 a	2.94 a	21.68 bc
F50	13.35	0.66 b	3.19 b	20.30 a
F100	26.71	0.81 d	3.65 c	20.18 a
S100	26.71	0.70 c	3.25 bc	21.26 b
S200	53.38	0.69 bc	3.10 b	22.01c

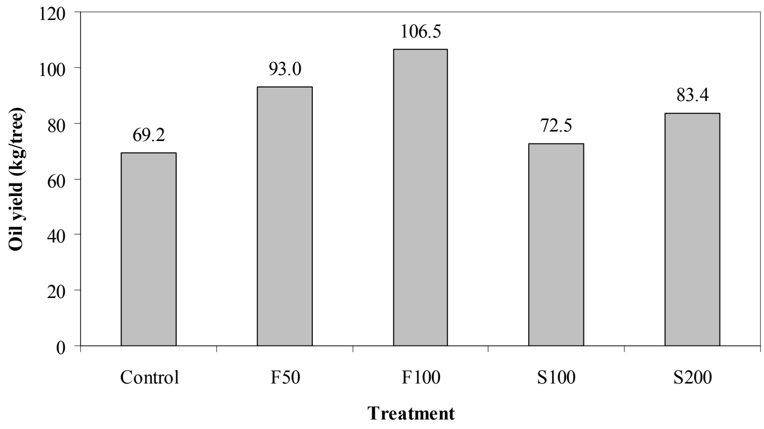

Fig. 4. Oil yield of olive trees for the different treatments (oil, kg/tree).

Conclusions

This study shows the importance of potassium fertilization in increasing the yield and oil yield of rainfed olive. The effect of split foliar application of potassium was superior to soil application which implies that this technology is preferable. Restrepo-Diaz *et al.* (2008) recommended foliar application in orchards growing under rainfed conditions because the lack of moisture in the soil during the growing period that could limit K uptake by the roots, which is the case for the majority of Tunisian olive orchards. Our calculations for potassium application rates based on removal of K in fruit and tree buds seem to be in good agreement. More work is still required in order to assess whether this balance is sustainable and profitable over longer periods. The results of this experiment demonstrate the need for a long term approach in such conditions, as both the fruit type (olive) and the climatic conditions pose a challenge in the analysis of data from field experiments.

Acknowledgements

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