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Response of Arbequina olive tree to reasonable fertilization

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Young Arbequina olive trees, growing in North of Tunisia, planted under irrigated system, were selected to reasonable fertilization since 2006 of Nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) distributed according to the critical stage of development of the tree. This fertilization was reasoned on foliar, flower diagnosis and the exportation in fruits, leaves and woods. Olive leaves were sampled at the pit hardening stage, the standard period for leaf sampling during 2006, 2007 and 2008. Inflorescence samples were taken at petal whitening stage. These samples were done to assess the effect of reasonable fertilization on the nutritional status of the olive. The fruit was chosen at maturity stage to determine the effect of the combined fertilization on oil content, fruit weight, yield and mineral composition of fruit. After the three years of experiment, results showed an improvement of nutritional status of Arbequina olive tree in micro and macro nutrients as well in flower as in leaves subjected to reasonable fertilization. Significant differences of potassium in fruits were found, showing a better assimilation of K in olive tree that had received the combined fertilizer. Average weight of the fruit per tree, oil content and yield increased with NPK fertilizer. Further work is required to assess the just needs of the olive trees in fertilizers to minimize their environmental impact and improve crop quality and yield.

Key words: Olive tree, reasonable fertilization, nutritional status, mineral composition.

INTRODUCTION

Tunisia is classified as a forefront regarding the areas devoted to production of olive. The Tunisian olive groves cover 72 million hectares which is about the 1/5 of the world surface corresponding to more than 74 million of olive trees. Olive tree cultivation has seen an important intensification in the last years. But this progress was not accompanied with progress in terms of irrigation and fertilization. In order to increase productivity and to improve olive oil quality, precautions such as trimming, irrigation, fertilization, protection and cultivation should be taken in time. The knowledge of the behavior of variety like Arbequina conducted under high density planting system and the evaluation of their nutritional status in irrigated farming conditions to elaborate programs of fertilization becomes a necessity to better administer the potentialities of the North of Tunisia and to give the best productions in this sector. Unfortunately, few research studies are dedicated to this theme. However, the actual fertilization practices in olive (*Olea europaea* L.) orchards are based mainly on tradition, repeating the same fertilization program every year, and also testimonial of the neighbors (Fernández-Escobar, 2004). Also, the excessive application of non-needed fertilizers causes environmental degradation (Gimenez et al., 2001). It negatively affects olive oil quality (Fernández-Escobar et al., 2006) and flower quality (Fernández-Escobar et al., 2008).

The reasonable fertilization consists therefore in

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adjusting the contributions of fertilizing elements and adapt them to the needs of the tree at the good moment to assure a sufficient yield and to minimize their secondary effects on the soil-tree - climate complex. The practice of reasonable fertilization is based on the analysis of the elements exported by the tree (leaves, fruits and woods). In this present research, a reasonable fertilization was done. This method permits to value the global needs of the tree and permits to estimate, at least, what is lost by the tree and to adjust the quantities of fertilizing elements to bring according to its stages of development. The goal was to evaluate the effect of the reasonable fertilization practice based on foliar and floral diagnosis on the nutritional status of Arbequina olive tree. Also, the relationships between nutritional status and oil content, yield and mineral composition of fruit were determined.

MATERIALS AND METHODS

Irrigated young olive trees of Arbequinal 18 variety (*O. europaea L.)* used for oil production with 4 years old (2006), spaced 2 × 4 m apart and growing in two parcels located in the experimental farm of Mornag region (North of Tunisia; 36° 39' N; 10° 16' E) were selected for the experiment. A randomized block experiment with two treatments T0: i) parcel without fertigation, TNPK: (ii) parcel that received the combined annual fertigation of N, P_2O_5 and K_2O from 2006 to 2008 and four blocks were established in each experimental parcel of 1.5 ha. The block or the experimental unit was composed of twelve trees. Nutrients were injected through drip irrigation. No other nutrient was supplied during the experiment since no problems with others elements were present in the experimental orchard. The orchard region in Mornag has a sandy-clayey texture. The source of nitrogen consisted of the nitrate of ammonium NH_4NO_3 (33.5%), the phosphor fertilization of phosphoric acid (50% of P_2O_5) and the potassium fertilization of K_2SO_4 (50% of K_2O).

Fertilization technique

We set up a program of fertilization with the aim of optimizing olive yield by the use of leaf analysis as a diagnostic tool for olive fertilization and the analysis of elements exported by the olive tree. This method allows the evaluation of the global necessities of the tree represented by the exportation element in leaves, fruits and wood and allows adjustment of the quantities of fertilizing elements to bring to the olive tree according to its stage of development. The physico - chemical analyses of the soil showed a level of fertility satisfying and no limitants factors that required a fertilization correction dose for the previous elements, to add to exportations.

Fruits samples

A sample of 100 g of fruits per block was taken, at maturity stage to determine the exportation of the mineral elements N, P, K in the fruit.

Wood samples

We determined the exportations of 5 trees of the experimental parcel and then we extrapolated for all the parcel of density of 1250 tree / ha. A sample of 60 g of every tree is taken for analysis of the various mineral elements: N, P, K then we calculated N, P_2O_5 and K_2O percentage.

Leaves samples

Mature leaves were sampled from the middle portion of non-bearing, current–season shoots to determine the exportation of the mineral elements in leaves at maturity stage. We estimated the exportations for the next year for an average production of 10T / ha for the variety Arbequina. We established a calendar of fertilization and the percentage of fertilizers for every element to cover the maximum of the need of the olive tree for the essential elements N, P_2O_5 and K_2O. Quantities of fertilizers were given according to the phenological stage of development of the olive tree. The nutritional status of the olive trees was determined every year by leaf and flower analysis. Leaves were collected 1.5 m above the ground, from Arbequina variety from 4 locations (East, South, West and North). Mature leaves were also sampled under natural growth conditions during 2006, 2007 and 2008 from the middle portion of non-bearing, current–season shoots. Olive leaves were collected at the pit hardening stage, the standard period for the sampling of leaves which correspond to the middle of July in the Mediterranean regions (Fernández -Escobar, 1997). One sample from each block was taken and was composed of 100 leaves for the determination of the nutrient concentration.

Inflorescence samples

Inflorescence were taken at the stage of white button (when the corolla changes from green to white colors), this stage is normally reached yearly at the end of April where the inflorescence development is completed at this stage (Bouranis et al., 1999). Complete inflorescences were collected from the middle of different reproductive shoots of the tree. Around 40 inflorescences at least were taken to have 4 g of dry matter from each block. Once in the laboratory, leaves and inflorescences were washed in deionized water, dried at 60°C, ground and stored in closed plastic containers until analysis. After leaves and flowers mineralization and mineral elements extraction, potassium and calcium amounts were measured by flame photometry. Iron (Fe), zinc (Zn), manganese (Mn), and magnesium (Mg) leaf and flowers contents are determined by atomic absorption. Whereas, phosphorus (P) and boron (B) amounts were analyzed by colorimetry, usingan UV spectrophotometer following the Olsen method for P and the method described by Lachica for B. Nitrogen was determined by the kjeldahl procedure. Results were expressed as a percentage of dry weight (% DW) for macronutrients [N, P, potassium (K), calcium (Ca), and Mg] and as parts per million of dry weight (ppm DW) for micronutrients (Fe, Zn, Mn and B). The effect of treatments on cropping was evaluated by measuring yield per tree at harvest. A sample of approximately 2 kg of fruits per block was taken at harvest to determine fruit weight and oil content. Fruit oil content was determined by nuclear magnetic resonance (NMR) after milling the fruit sample. Oil was extracted by an Abencor analyzer after mixing the fruit paste at 30°C during 30 min. Another sample of 100 g of fruits per block was taken at maturity stage to determine the effect of the combined fertilization on mineral composition of fruits.

Fruits were washed in the distilled water, dried at 105°C. Then, all the fruit was crushed by means of porcelain mortar, and then we determined the exportations of the mineral elements in the fruit (N, P and K). These fruits crushed followed the same procedures of mineralization and mineral analyses such as leaves and flowers. Results were expressed as a percentage of dry weight for N P and k.

Table 1. Results of exportations in N, P and K in fruits, leaves and big wood of Arbequina olive trees.

Exportations in fertilisant element (%)	Fruit	Big wood	Leaves
N	0.7	2.2	1.8
P	0.16	0.21	0.15
K	1.9	0.5	1.0

Table 2. Results of exportations in N, P_2O_5 and K_2O in fruit, leaves and big wood of Arbequina olive trees for an average production of 10T ha^{-1}.

Exportations in fertilisant element (kg ha^{-1})	Fruits	Big wood + leaves	Total of exportations
N	37	80	120
P_2O_5	20	18	40
K_2O	123	36	160

Statistical analysis

Analyses of variance were performed at risk of 5% on the data to compare the effects of the treatments. It is completed by a multiple comparison of averages by the test of Newman and Keuls.

RESULTS

Exportations in N, P and K in fruits, leaves and big woods of Arbequina olive trees

We noted, according to Table 1 that exportations in nitrogen, are more important in leaves (1.8 %) for the maturity stage than in fruits (0.7%). Indeed, the olive tree reconstitutes its reserves in organs sources (old leaves, twigs), from August to November to make its stock of nitrogen that it mobilizes the next year. Exportations in phosphor are more raised in the big wood (0.21%) than in leaves (0.15), so we noticed a weak incidence, of the transfer of the phosphor, towards fruits on its content in leaves. However, exportations in potassium are higher in fruits (1.9%) than in leaves (1.0%) and big wood (0.5%) (Table 1). The results of the exportations in N, P_2O_5 and K_2O were represented in Table 2. The evaluation of the exportations was done for an average production of 10T / ha for the variety Arbequina.

The doses of reasonable fertigation programs proposed

The percentages of fertilizers were established for every element to cover the maximum of needs of the olive tree for the essential elements N, P_2O_5 and K_2O. The percentage of nitrogen fertilizer is high, especially during the beginning of flowering (30%) because the olives will develop stems, leaves, flowers and fruit development through the mobilization of reserves from the source organs, which require a high level of nitrogen during this period. The remainder of the dose was given at fruit set stage (20%), fruit development and stone hardening stage (20%) and at fruit color break (20%) (Table 3). The phosphor fertilizer is applied especially with the beginning of the root activity, at cluster development stage (30%), flowering (30%) and fruit development (15%) (Table 3). The potassium fertilizer is split during the period of fruit development from fruit set to fruit color break stage. After fractionation indicated in Table 3, we deduced the quantities of fertilizers given according to the phenological stage of development of the olive tree and represented 120 kg N ha^{-1}; 40 kg P_2O_5 ha^{-1} and 160 kg K_2O ha^{-1} (Table 3).

Effect of reasonable fertilization on the nutritional status of olive tree: Annual changes in leaf and flower nutrient concentration

Nitrogen concentration in leaves was always above the critical threshold established by Fernández -Escobar (1997) of 1.40% in trees that received NPK treatments in the three years of study (Figure 1A). On the contrary, it was below this deficiency threshold in control trees exception in 2007 year (1.53% of DW). Leaf N concentration increased in 2007 year in both treatments (T0 and NPK treatment) reaching values above the deficiency threshold (Figure 1A). In fact, 2007 is supposed an 'off' year that's why there is accumulation of N during this year. In 2006 and 2008 year, nitrogen concentration in flowers was more raised in trees having received treatments of NPK, then in control trees (T0) and above the critical threshold of N in flowers of 1.8% of DW proposed in the study carried out in North and North-East of Tunisia on Arbequina planted under irrigated condition to permit early diagnosis of the nutritional olive tree (Ben Khelil, 2010a, b) (Figure 1B). Also, flowers N concentration increased in 2007 year in both treatments as well in leaves. Moreover, a relationship was found

Table 3. Percentages and quantities of fertilizers given according to the phenological stage of development of the olive tree.

Phenological stage	Percentages and quantities of fertilizers given according to phenological stage					
	N (%)	N (Kg ha^{-1})	P_2O_5 (%)	P_2O_5 (kg ha^{-1})	K_2O (%)	K_2O (kg ha^{-1})
Cluster development	10	12	30	12	-	-
Beginning of bloom	30	36	30	12	-	-
Fruit set	20	24	15	6	25	40
Fruit development and stone hardening	20	24	15	6	50	80
Fruit color break	20	24	10	4	25	40
Total	100	120	100	40	100	160

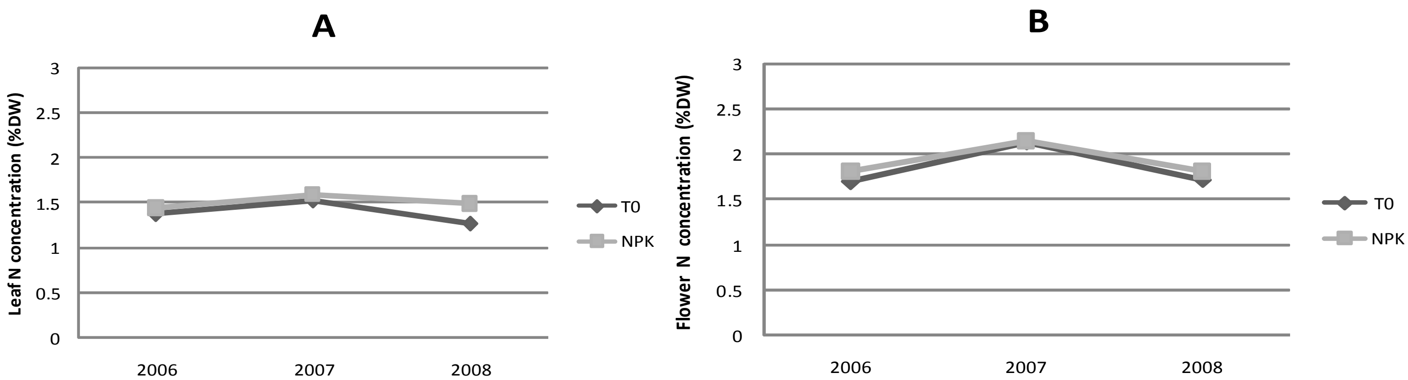

Figure 1. Effect of reasonable fertilization on leaf N concentration (A) and flower N concentration (B) of Arbequina olive tree in the three years of experiment.

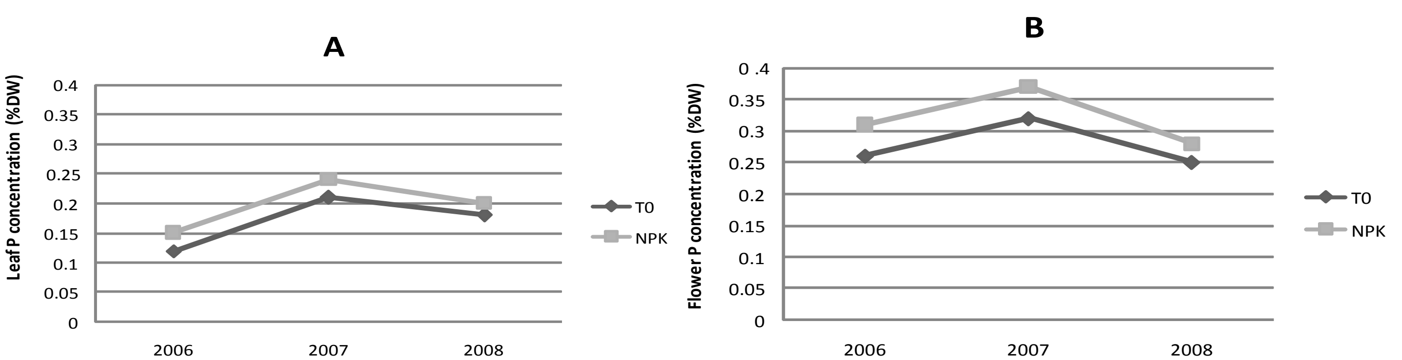

Figure 2. Effect of reasonable fertilization on leaf P concentration (A) and flower P concentration (B) of Arbequina olive tree in the three years of experiment.

between leaves and flowers nutrient concentrations in our previous work enables us to use flower diagnosis as a new approach to evaluate the nutritional status of olive tree (Ben Khelil et al., 2010a, b) (Figure 1B).

Phosphorous concentration in leaves was above the critical threshold for the phosphor established by Buchman et al. (1959) in irrigated Tunisian olive groves of 0.095% of DW in all treatments or the three years reaching the value of 0.24% of DW in 2007 (Figure 2A). P concentration in flowers was higher in trees of the combined treatment in comparison to control trees in all years (Figure 2B). In 2006, phosphor concentration in flowers ranged between 0.32% in trees having received NPK treatments and 0.25% in control trees (T0). In 2007, it ranged between 0.37% (NPK) and 0.29% (T0) and between 0.31% (NPK) and 0.26% (T0) in 2008. Leaf K concentrations of July for the three years of study, were all above thresholds proposed by Buchman et al. (1959) in Tunisia of 0.74% for the irrigated olive tree and by Fernández -Escobar (1997) of 0.8% (Figure 3A). Flower K concentration was higher in trees of the combined treatment in comparison to control trees in the three

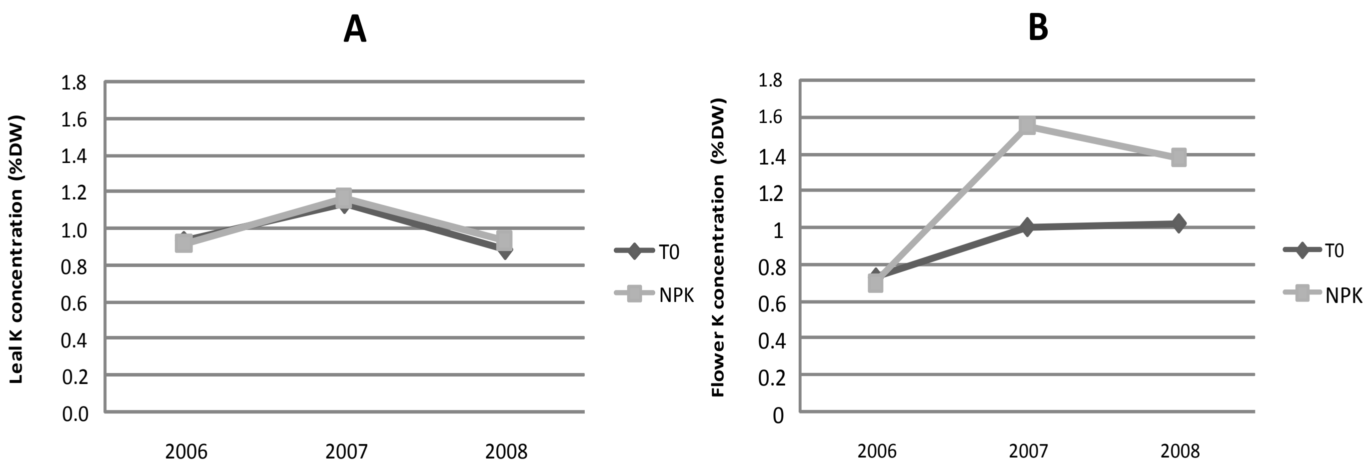

Figure 3. Effect of reasonable fertilization on leaf K concentration (A) and flower K concentration (B) of Arbequina olive tree in the three years of experiment.

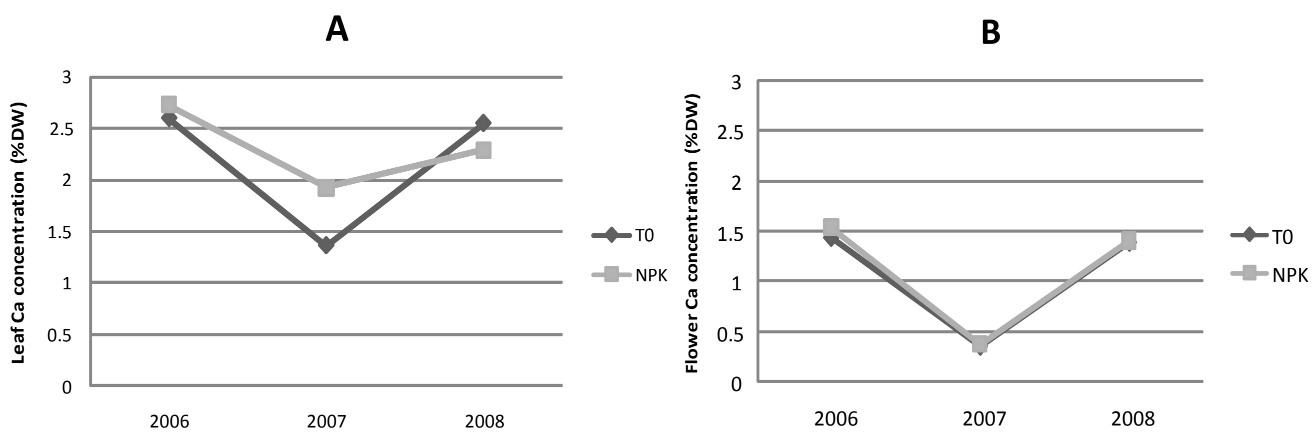

Figure 4. Effect of reasonable fertilization on leaf Ca concentration (A) and flower Ca concentration (B) of Arbequina olive tree in the three years of experiment.

years and always above the critical threshold of K in flowers of 1.12 % of DW proposed in the study carried out in North and North-East of Tunisia by Ben Khelil (2010) on Arbequina olive tree, exception in 2006 where it ranged between 0.73% in trees having received treatments of NPK and 0.7% in control one (T0). Flower and leave K concentrations were the most elevated in 2007 (Figure 3A and B).

Leaf Ca concentration was always above the sufficiency level of 1% by Fernández -Escobar (1997), in all treatments in the orchards (Figure 4A) and in the margin of standards level of 1.16 and 2.17% for the three years of study. This shows that the studied orchard does not suffer from deficiency in this element. Leaf Ca concentration decreased in 2007, which was an 'off' year in both treatment, reaching value of 1.36% and also in flower concentration reaching the value of 0.35% (Figure 4B). Indeed, calcium contents is related to the levels of productions (fruit load) of the trees and has a strong relationship of alternative bearing. The same tendency was observed with Mg. Leaf Mg concentration was always above the sufficiency level of 0.1% by Fernández –Escobar (1997) and in the margin of sufficiency level of 0.08 and 0.15% proposed by De Monpezat et al. (2000) for both treatments (Figure 5A). The studied orchard does not suffer from deficiency in this element. Also, flower Mg concentration was above the critical threshold of Mg in flowers of 0.11% of DW proposed in the study carried out by Ben Khelil (2010) exception in 2007 (Figure 5B). In this study, leaf B concentration was always above the critical level of 14 ppm exception for control trees in 2007 and in many cases above the sufficiency level of 19 ppm (Figure 6A). Flower B concentration was a little raised in trees of the combined treatment in comparison to control trees in the three years of experiment (Figure 6B). Consequently, no B application was practiced along the experiment in blocks of the treatment based on foliar and flower diagnosis.

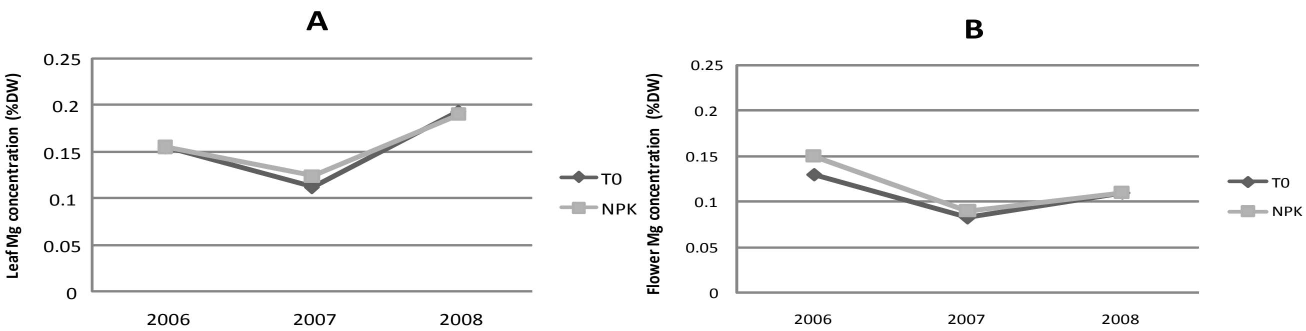

Figure 5. Effect of reasonable fertilization on leaf Mg concentration (A) and flower Mg concentration (B) of Arbequina olive tree in the three years of experiment.

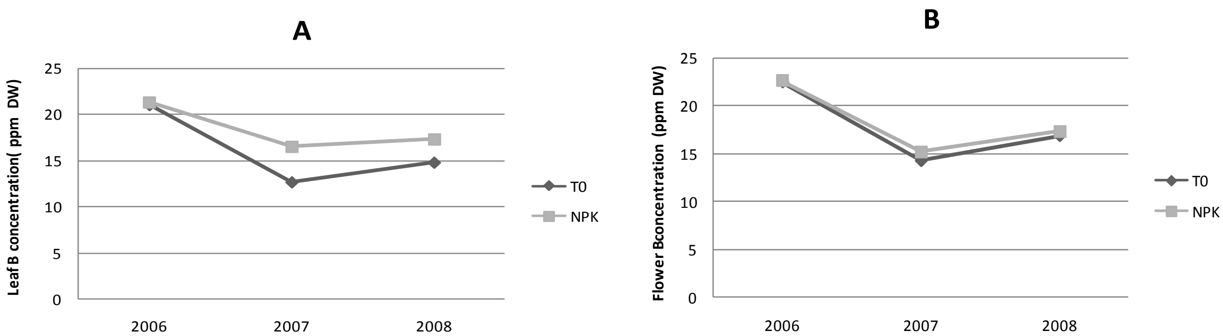

Figure 6. Effect of reasonable fertilization on leaf B concentration (A) and flower B concentration (B) of Arbequina olive tree in the three years of experiment.

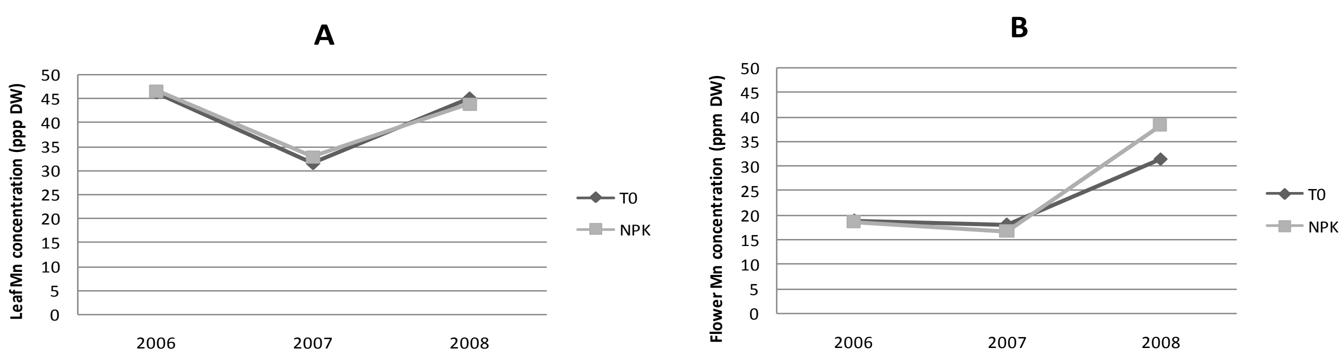

Figure 7. Effect of reasonable fertilization on leaf Mn concentration (A) and flower Mn concentration (B) of Arbequina olive tree in the three years of experiment.

The same behavior was observed with other micronutrients such as Mn (Figure 7A and B), Zn (Figure 8A and B) or Fe (Figure 9A and B).

Effect of reasonable fertilization on fruit weight, yield, oil content and mineral composition of fruit of Arbequina olive trees

The fruit mean weight of olives at harvest was equal to 2.05 g for the treatment NPK and was higher compared to the control which is equal to 1.9 g during the first year. However, it was lower in the second year for the NPK treatment equal to 2.86 g compared to control (2.97 g). In the third year, levels were almost similar for the control (2.25 g) and treatment NPK (2.28 g) (Table 4). The final yield for Arbequina olives has been improved for trees that received the tri-factorial program (N, P, K) compared to the control. In fact, the yield of trees that have received treatment NPK for the year 2006 was 10.54 kg tree^{-1} compared to control equal to 9.2 kg tree^{-1}. However,

Table 4. The effect of reasonable fertilization on yield (kg tree^{-1}), fruit weight, oil content and mineral composition of fruit of olive trees during the three years of study.

Year	Fruit weight (g)	Yield (kg tree $^{-1}$)	Oil content (% FW)	Mineral composition of fruit (% DW)		
				N	P	K
2006						
T0	1.90^a	9.20^a	16.54^a	0.64^a	0.17^a	1.02^a
NPK	2.05^a	10.54^a	17.20^a	0.68^b	0.16^a	1.12^b
2007						
Témoin	2.86^a	7.07^a	15.20	0.52^a	0.15^a	1.16^a
NPK	2.97^a	8.32^a	15.70	0.97^b	0.13^a	1.22^b
2008						
Témoin	2.25^a	6.30^a	16.07	0.70^a	0.13^a	1.18^a
NPK	2.28^a	8.13^a	16.51	0.87^b	0.18^b	1.20^a

Averages followed from different letters for every year are significantly different at the level of 5% of probability according to the test of Newman and Keuls.

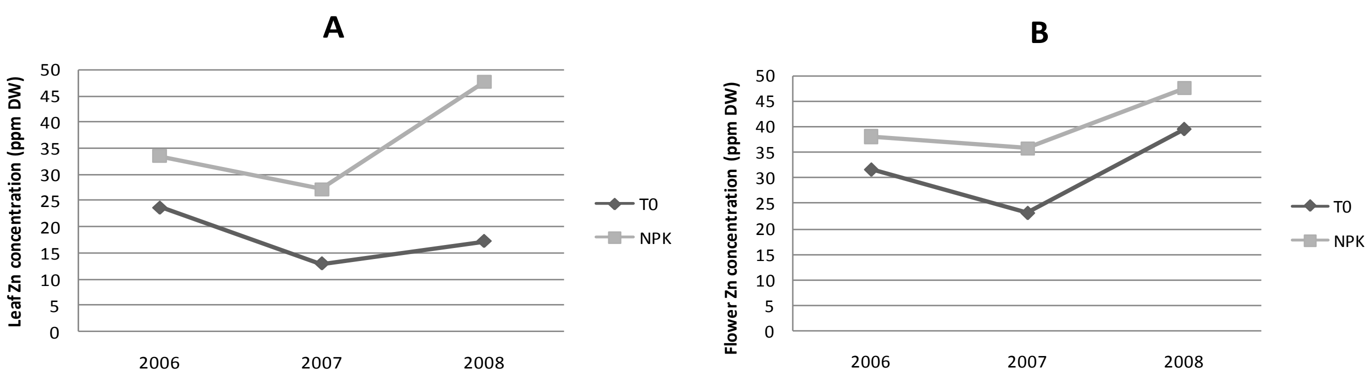

Figure 8. Effect of reasonable fertilization on leaf Zn concentration (A) and flower Zn concentration (B) of Arbequina olive tree in the three years of experiment.

there is a decrease in the yield for the two treatments for the following year. Yields were respectively 7.07 kg tree^{-1} for the control and 8.32 kg tree^{-1} for the treatment NPK. It was noted that the decrease in yield is lower for NPK treatment compared to the control, which is generated by an improvement in the mineral nutrition provided at critical stages of development of olive tree. In 2008, there was also a decrease in yield of control trees which was equal to 6.3 kg tree^{-1}. However, yield remained stationary for the treatment NPK (8.13 kg tree^{-1}) compared to the previous year (Table 4). Oil content for olive who received treatment NPK for 2006 was 17.2% compared to control equal to 16.54%. However, there is a decrease in oil content for the two treatments for the following year. Levels of oils obtained were 15.7% for the NPK treatment compared to control equal to 15.2% in 2007 (Table 4). This decrease is due to growing and weather conditions during the process of lipogenesis. Indeed, the oil content that has been accumulated in the olive harvest is largely determined by variety, but it may vary significantly on the growing conditions, climate and fruit load of trees.

In the third year of study, the oil content was also higher for the treatment NPK (16.51%) compared to control (16.07%). This improvement in oil content for the three years of study is due to the improvement of the nutritional status of nitrogen and phospho-potassium by treatments made especially during vegetative growth that enhance the photosynthetic capacity of tree and fertilizer made during fruit development and lipogenesis. The total nitrogen content in olives ranged from 0.64 to 0.68% DM (2006), from 0.52 to 0.97% DW (2007) and 0.7 to 0.87% DW (2008). The nitrogen olives to harvest trees that received NPK treatments significantly decreased compared with the control for the three years (Table 4). This decrease in nitrogen content seems to have an effect on improving the quality of the fruit. The mineral analysis did not show any effect on the phosphorus content of olives that received NPK treatments and the

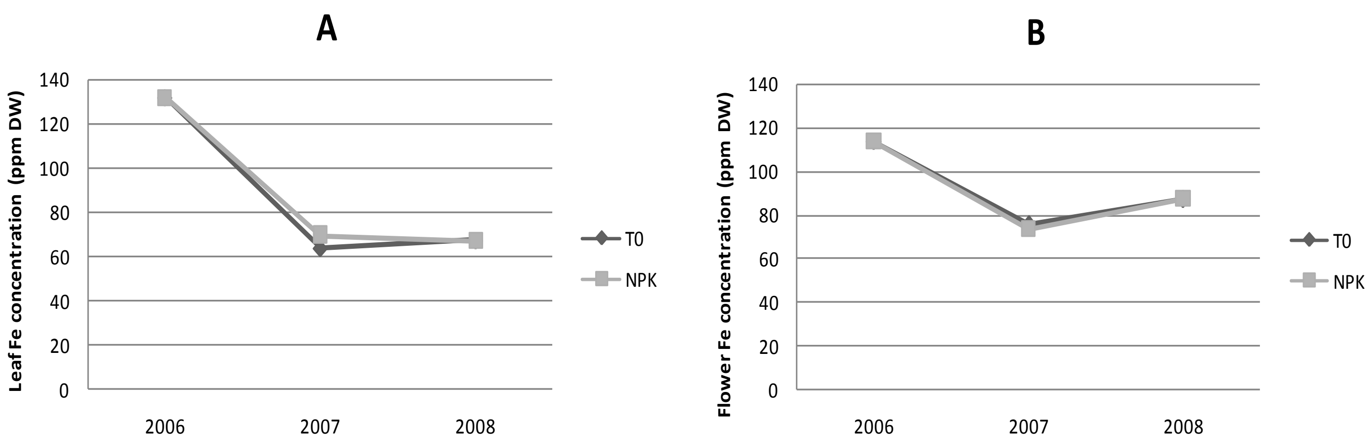

Figure 9. Effect of reasonable fertilization on leaf Fe concentration (A) and flower Fe concentration (B) of Arbequina olive tree in the three years of experiment.

control, with the exception of last year when the level was significantly increased for NPK compared to control equal to 0.13% DW. The variation in potassium content in fruits of olives trees that received NPK treatments and the control was significant for the first two years. Indeed, there is an improvement in levels of potassium in the treatment NPK respectively equal to 1.12 (2006) and 1.22% DW (2007) compared to the control equal to 1.02 and 1.11% DW, showing a better assimilation of K in the fruit (Table 4).

DISCUSSION

Exportations in N, P and K in fruits, leaves and big woods of Arbequina olive trees

Results of exportations in potassium are higher in fruits than in leaves and big wood. This shows a better translocation of the potassium towards the fruit. According to Soing (1999), the potassium is very mobile in the plant and according Buchman (1962) necessities in potassium continue to increase from August to November to reach at the time of harvest 60% of the total potassium of the tree, so this will be emptied in leaves to satisfy the necessities of fruits in K. Also, potassium is the most nutrients exported by the olive tree. Indeed, studies conducted by Chaves (1975) showed that in the ashes of olive plants, the potassium is the most represented in comparison with nitrogen, phosphorus and calcium.

Effect of reasonable fertilization on the nutritional status of olive tree: Annual changes in leaf and flower nutrient concentration

Nitrogenous fertilization brought in NPK treatments, improved vegetative growth (data not shown) (Ben Khelil, 2010) and the translocation of nitrogen of the old leaves towards the new structures of olive trees and young leaves (Bouat et al., 1953, 1954; Crescimanno, 1963; Crescimanno et al., 1975; Fernández-Escobar et al., 1999). This has an influence on the nutritional status of the olive tree by improving the concentration of nitrogen in leaves exception in 2007 year (1.53% of DW). Leaf N concentration increased in 2007 (off' year) in both treatments (T0 and NPK treatment) reaching values above the deficiency threshold. The same result was observed by Brown et al. (1995) in pistachio tree and Fahmy and Nasrallah (1959), Fernández -Escobar et al. (1999) and Troncoso et al. (2006) in olive tree. P flower concentration showed the same pattern as P concentration in leaves for the three years but it was always more raised than in leaves. The same results were observed for P concentration in flowers which were higher than those of leaves collected at 60 and 120 days after bloom (Sanz and Montanes, 1995) and also in coffee tree flowers (Martiınez Herminia et al., 2003). They reported that P concentrations were higher in flowers because P is a phloem mobile element, which accumulates in reproductive organs where it carries out important functions in the polinic tube growth, pollen grain maturation and the first phase of fruit formation.

Potassium brought in NPK treatment at the time of the fruit set until fruit development had improved leaf K concentration. Buchman (1962) noted that the most important yields result from leaves of olive trees which are the richest in potassium. Also, necessities in K were more important in intensive farming and increased as we approached optimal productions. The assimilation of K was better in 2007 which was a wet year. Indeed, according to Restrepo et al. (2008), the water condition seems to influence the uptake of K by the olive tree. An improvement of nutritional status of Arbequina olive tree in macro nutrients as well in flower as in leaves subjected to reasonable fertilization. The same behavior was observed with other micronutrients such as Mn, Zn and B. In fact, olive trees required high level of B mainly during flowering and fruit development (Delgado et al., 1994). Standard values for Fe have not been established for olive tree. As for other species, leaf analysis is not useful for diagnosing Fe deficiency because of paradox phenomenon, the best method is the visual examination of the tree (Fernández -Escobar et al., 1999).

Effect of reasonable fertilization on fruit weight, yield, oil content and mineral composition of fruit of Arbequina olive trees

An improvement of average weight of the fruits per tree which had received rational fertilization with regard to control (T0) has been showed, probably because the better assimilation of potassium in fruits. All the values for the three years of experiment were higher than the average weight of fruit per tree of the same variety grown in Spain, which was 1.86 g (Tous and Romero, 2000). This difference could be explained by the influence of the environment and by providing water and fertilizers to olive trees (Aouini, 2006). In fact, significant differences of potassium concentration in olives between control trees and trees subjected to combined fertilization of N-P-K for the first two years, was observed (Table 4). This improvement of K concentration in olives shows a better assimilation of K in fruits. These results suit to those of Morales-Sillero et al. (2007) that noticed an influence of NPK fertigation on the content of water in olives of the variety "Manzanille" which increased with the quantity of fertilizer brought, probably because of the increase of the potassium in the pulp. The mineral analysis did not show any effect in the concentration of phosphor in olives with the exception of the last year when P concentration in fruit increased significantly for NPK treatments in comparison to the control equal to 0.13% (Table 4). A significant increase of N concentration in fruits having received the annual NPK fertilizer in comparison to control trees was observed. Studies realized by Fernández -Escobar et al. (2006) on Picual olive tree showed that the accumulation of N in fruit by N over fertilization affects negatively olive oil quality.

The final yield for Arbequina olives has been improved for trees that received the tri-factorial program (N, P, K) compared to control in the three years of study (Table 4). An improvement of cumulative yield for three successive years of 20% for trees subjected to reasonable fertilization was observed. Content in oil was increased also. This progress in oil content for the three years of study is due to the improvement of nutritional status in micro and macro nutrients. This is noticed further to fertilizing brought at just moment and during the critical stages of development of olive tree. Indeed, the accumulation of the oil in the olive is a process which depends on the quantity of the carbohydrates resulting from fruits and old leaves (Conde et al., 2008). In summary, we can conclude after three years of experiment that reasonable fertilization allowed the improvement of nutritional status of Arbequina olive tree in micro and macro nutrients as well in flower as in leaves. In fact, we noted that N, P, K, Ca and Mg concentrations in leaves, subjected to the combined fertilizer were always above the critical thresholds in leaves taken at the stage of pit hardening (in July), considered as standard stage of leaf sampling. The same behavior was observed with other micronutrients such as Mn, Zn and B. Also, an improvement of flower status was observed in fertilized trees in comparison to control trees. A better mineral assimilation in fruits was showed, especially in K and P. This improvement of assimilation of those elements was due to the combined NPK treatments, given at just dose and at the good moment.

Fruit mean weight, oil content and yield increased with NPK fertilizer. When fertilization is reasoned on foliar, flower diagnosis and the exportation in fruits, leaves and woods, we satisfy the nutritional needs of the olive trees, minimize the environmental impact, improve crop quality and yield and prevent the excessive and systematic use of fertilizers.

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