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**Title**

The role of macro-nutrients in olive tree flowering and fruit set

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## Introduction

Olive (*Olea europaea* L.) is a traditionally important crop grown extensively in the Mediterranean basin. Recent modernization of olive cultivation has introduced and promoted densely planted orchards that are irrigated via systems that can also be utilized for nutrient application (Fernández-Escobar et al., 2006).

Flowering and fruit set are the main processes influencing the productivity of fruit trees and are particularly important for olive, where there is an apparently delicate relationship between vegetative and reproductive stages of growth (Lavee, 2006). Olive trees are known to require essential minerals at levels comparable with those of other fruit trees (Therios, 2006). N fertilization was reported to increase fruit set in olive (Cimato et al., 1990). Information relating P fertilization to reproductive and vegetative growth and function in olives is limited. Generally, P fertilization is not recommended or practiced in rain-fed olive orchards (Therios, 2006). Potassium fertilization is considered essential in olive, particularly because K is found in high concentration in the fruit (López-Villalta, 1996). However, most of the data supporting this have been collected under rain-fed conditions where the nutrients were either applied to the soil before the rainy season or occasionally sprayed onto the foliage. Little is known regarding the effects of nutrients supplied intensively via the irrigation water throughout the growing season as is becoming common practice in intensively managed olive orchards. We have previously demonstrated that macronutrient mineral status influences the productive stages of young olive trees (Erel et al., 2008). The objective of the present work was to continue and expand the study of independent effects of N, P and K concentrations in irrigation solution on flowering and fruit set in olive trees.

## Materials and Methods

Olives (*Olea europaea* L. cv. Barnea) were grown in containers filled with perlite substrate at the Gilat Research Center, Israel. The 20 treatments included eight levels of N ranging from 5 to 202 ppm (N1-N8), seven levels of P ranging from 0.2 to 20 ppm (P1-P7) and seven levels of K ranging from 10 to 200 ppm (K1-K7). Nutrient solutions were prepared in containers containing a full regime of all additional nutrient elements. In all treatments, N was allocated as 90%  $\text{NO}_3^-$  and 10%  $\text{NH}_4^+$ . Monitoring of irrigation solution minerals via measurements made every 2 to 3 weeks insured stable and correct concentrations. Irrigation quantity was set to obtain 30% drainage by volume. The experiment used a randomized block design with six replications in 2007 and three replications in 2008. Leaves were sampled in May according to the common protocol for olives. Total N, P and K contents of the leaves were determined after digestion with sulfuric acid and peroxide. Flowering intensity was appraised by visual evaluation using a scale of 1 to 100 with 100 denoting full flowering potential. Sections of four branches per tree, each containing exactly 100 flowers, were labeled during the flowering period. These branches were used to measure fruit set in May. Results are presented as percentage of flowers resulting in viable fruits.

## Results

With the exception of the two lowest N treatments, for which growth was low, no significant differences were found between treatments (data not shown). This implies that, although vegetative growth of the trees during the experimental period was substantial, it was not affected by either P or K nutrition and was reduced only at the lowest two N concentrations.

### *Nitrogen*

Flowering intensity was highly dependent on the concentration of N (Fig. 1A). Flowering at the lowest N treatment (no N addition, 5 ppm N) was very low for both seasons. Presentation

of flowering intensity as a function of content in leaf matter revealed a second-order polynomial rising and falling response curve. Maximum flower intensity was achieved when leaf N content was between 1.5-1.7%

Fruit set was affected similarly to flowering by N. Fruit set when no N was added was nearly zero and increased to 8.0% and 6.2% for 2007 and 2008 respectively when N in solution reached 50 ppm. The highest N concentrations caused reductions in fruit set. The maximum fruit set occurred when leaf N content was 1.6-1.7% (Fig. 1C).

Following the trends seen for flowering and fruit set, the final number of fruit remaining on individual trees was also a function of N. Fruit number per tree increased drastically when solution N concentration increased from 5 to 50 ppm and decreased from this maximum as N concentration was further increased to 200 ppm.

### Phosphorus

Flowering intensity was affected by P only when no P was added to the irrigation solution. P concentration higher than 0.5 ppm resulted in high flowering intensity (Fig. 1B).

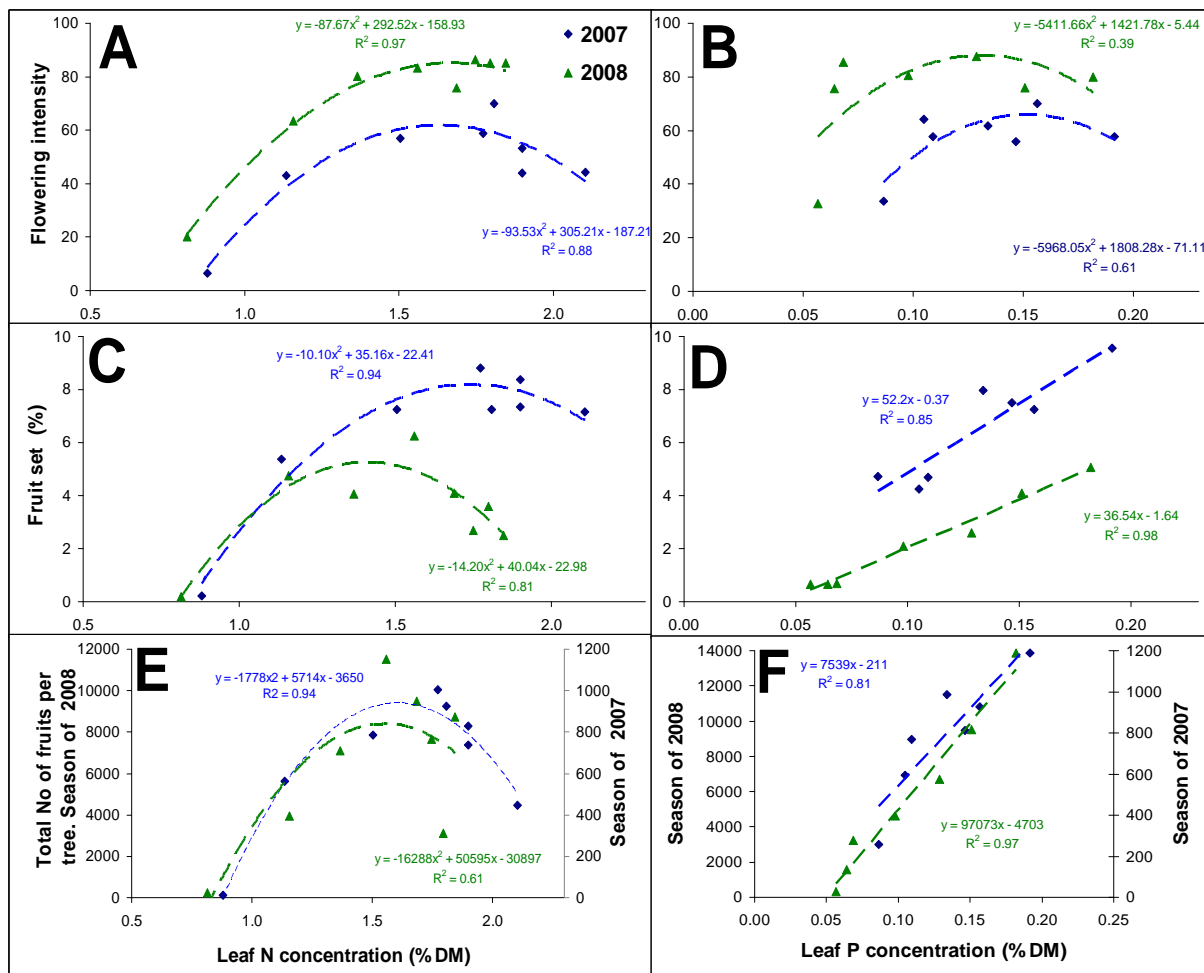


Fig. 1. Flowering intensity (A,B), fruit set (C, D) and No. of fruits per tree (E, F) as effected by leaf N (A, C, E) and leaf P (B, D, F) concentration for two successive years. Average data from the 2007 (n=6) season are presented as blue diamonds and from the 2008 (n=3) season as green triangles. Due to disparity in yields, total No. of fruits from 2008 is presented on the left Y axis and that from 2007 on the right Y axis.

The fruit set at the three lowest concentrations (P1-P3) was very similar and low. The fruit set response to leaf P content (Fig. 1D) was significantly linear.

Total number of fruits was also a function of P concentration. Fruit number per tree increased continually when P concentration in the irrigation water increased. Fruit number as a function of leaf P content increased with increasing P content and was defined by a linear curve with maximum fruits corresponding to the maximum measured P in leaves.

### Potassium

Flowering intensity increased as a function of solution K concentration only in the season of 2007 (Table 1), increasing from 45 to 69 when K in the irrigation solution increased from 8 to 81 ppm. K6 treatment had significantly higher flowering intensity than K1. In 2008 all K treatments had high flowering intensity.

Fruit set was high for all K treatments and was not found to be a function of either solution or leaf K levels (Table 1). The K3 treatment had a relatively low fruit set in 2008.

Increases from 8 to over 200 ppm K in solution did not result in any changes in fruit number.

Table 1. Flowering intensity, fruit set and No' of fruits per tree for the potassium treatments for the 2007 (n=6) and 2008 (n=3) seasons. Different letters indicate significant differences between means found by the Tukey-Kramer test.

| Treatment | 2007           |                        |           |               | 2008                   |           |               |
|-----------|----------------|------------------------|-----------|---------------|------------------------|-----------|---------------|
|           | K conc.<br>ppm | Flowering<br>intensity | Fruit set | No' of fruits | Flowering<br>intensity | Fruit set | No' of fruits |
|           |                | %                      | %         |               | %                      | %         |               |
| K1        | 8              | 45 A                   | 10.2 A    | 1034 A        | 85 A                   | 3.1 AB    | 8319 A        |
| K2        | 18             | 50 AB                  | 6.3 A     | 725 A         | 78 A                   | 5.4 AB    | 8831 A        |
| K3        | 30             | 60 AB                  | 7.9 A     | 873 A         | 86 A                   | 1.1 B     | 4233 A        |
| K4        | 52             | 66 AB                  | 9.2 A     | 1297 A        | 79 A                   | 5.1 AB    | 7820 A        |
| K5        | 81             | 69 AB                  | 7.0 A     | 1124 A        | 78 A                   | 3.3 AB    | 6155 A        |
| K6        | 101            | 70 B                   | 7.5 A     | 925 A         | 76 A                   | 4.1 AB    | 9495 A        |
| K7        | 209            | 68 AB                  | 8.2 A     | 1158 A        | 74 A                   | 5.9 A     | 10740 A       |

### Conclusions

Availability of the macroelements N and P but not K was found to influence flowering intensity and fruit set of olive trees. Fruit load increased to a maximum as leaf N increased from 1 to 1.7% and then decreased as leaf N increased further. This trend indicates the negative influence of nitrogen over-fertilization on olive tree fertility. Negative effects of nitrogen on olive oil (Fernandez-Escobar et al., 2006) and flowering quality (Fernandez-Escobar et al., 2008) have been previously reported. Total fruit load of olives increased appreciably as P in the leaves increased. Maximum fruit load corresponded to approximately 0.2% P in the leaves. Regular P application of olive orchards is not common. The results of this study suggest that under intensive growing conditions P application might be beneficially. Potassium had little if any affect on tree vigor and productivity in spite of the large range of K supplied in the irrigation solution and found in the leaves. This suggests that irrigation lowers the olive tree's demand for K, probably as a result of higher mineral availability. Thus, in regularly irrigated orchards, K fertilizer might be reduced without threatening productivity.

As olive production advances into intensive cultivation practices, including season-long application of fertilizers in the irrigation water, management of nutrient application to optimize availability for maximum production is becoming a necessity. Further research is necessary to support this study's findings under field conditions.

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