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RESPONSE OF DIFFERENT IRRIGATION DEPTHS AND NUTRIENTS UPTAKE TO VEGETATIVE GROWTH OF YOUNG OLIVE CULTIVARS

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Abstract

The response of different irrigation depths on vegetative growth and nutrient uptake of young trees of different olive cultivars i.e., Baincullela, Leccino, and Frantoio were studied. The experiment was laid out in split plot design having four irrigation depths with three replications. The soil analysis was done at the start and end of the experiment. Potential evapo-transpiration and rainfall were measured daily accordingly. Drippers were adjusted each time according to the water requirement and according to the depth. The moisture content of the soil was determined at different irrigation depths (30, 60, and 90 cm) with gravimetric method on monthly basis. The irrigation water was applied for 100, 80, 60 and 40% amount of relative irrigation depths release as for pan evapo-transpiration consumption. The data for shoot growth, shoot diameter, leaf area and leaf water content were recorded. The results showed significant variations in all studied parameters with respect to both irrigation depths and cultivars, except leaf area. Different irrigation depths as well cultivar's type substantially affected the nutrient uptake. The maximum nitrogen, phosphorous and potassium uptake were recorded with controlled irrigation depth in cv. Frantoio. It was concluded that well water application has best performance with cv. Frantoio.

Key word: Olive, Irrigation depth, Nutrient uptake and Cultivars.

INTRODUCTION

Olive (*Olea europaea* L.) locally called Zaitoon or Khuna (Khyber Pakhtunkhwa, Pakistan), belongs to family Oleaceae. Olive is a medium to tall evergreen tree reaching upto 15 m. The centre of origin of olive includes Palestine, Lebanon, North West Syria and Cyprus. Its cultivation in Italy, Spain and North Africa began later than in the eastern Mediterranean region (Simmonds, 1976).

The highest crop productivity is achieved for high-yielding varieties with optimal water supply and high soil fertility levels, but under conditions of limited water supply crops will adapt to water stress and can produce well with less water (FAO, 2002). The uptake of nutrients such as nitrogen, phosphorus and potassium (NPK) is mainly affected by the amount of water applied to the crop, as water is the agent to transport the nutrient to different parts of the crop. The primary purpose of the irrigation system is to provide water and nutrients in such a way that these resources do not limit crop growth and development (Lebote et al., 1998). Cetin et al. (2004) reported that agricultural growers needed investment and cost guidelines for drip irrigation to evaluate the economics of getting crops into production as quickly

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as possible and to minimize economic losses from drought during the productive life of an olive orchard. The benefits of irrigation may include; better olive survival, earlier crop production, greater yields, efficient nutrient distribution and less plant stress reduced yield variability and improved crop quality. Connor and Fereres (2005) reported that due to olive higher planting densities, better plant material, and irrigation systems, new olive orchards demand a large capital investment. Irrigation allows young trees to grow more quickly, thus reducing the period during which fruit production is limited or nil. The olive has a long-respected reputation of being drought tolerant but few field studies have been undertaken to determine its response to water deficit during the first years after planting.

MATERIALS AND METHODS

The effect of different irrigation depths on vegetative growth and nutrient uptake of young olive cultivars (Bincolilla, Leccino, and Frantoio) was studied during 2011under field conditions of Agriculture Research Institute, Tarnab, Peshawar. The area of the whole orchard was 1.665 acres including 200 trees, the orchard was laid out as 6×3m tree to tree and row to row distances, while the Experimental field consists of one block with three sub-plots and each plot had twelve olive plants of three different cultivars. For nutrients analysis, the soil samplings were taken for each tree at a depth of 0-30cm and 30-60cm before the start and end of the studies. About one kg of the composite sample was taken through mixing of 10-15 sub samples. The samples were air dried and grinded with wooden mortar and passed through 2mm Nylon sieve, finally packed in the plastic bags and labeled for conducting analysis. The pH of the soil was determined with pH meter, which were 8.15. Organic matter was determined by Dichromate Oxidation method and was found 0.83 %. Mineral N was determined by using FAO (1980), while P and K by AB-DPTA techniques. The soil samples were taken with monthly intervals to determine the soil moisture content by using gravimetric method.

Data recording procedure: Evapo-transpiration (ET_O) was calculated by Pan Evaporation method. Evaporation pans provide a measurement of the combined effect of temperature, humidity, wind speed and sunshine on the reference crop ETo.

Growth rate (cm): Monthly growth increment / rate were measured with the help of meter rod as an increase in length from selected point on each branch of each treatment.

Shoot diameter/thickness: Monthly shoot diameter was measured with help of vernier caliper as an increase in diameter from selected point on each branch of each treatment.

Leaf area (cm^2): Leaf area data was measured with help of leaf area meter (Licor®) by taking leaves from selected branches in each treatment and then average leaf area was calculated.

Leaf water content: Leaf water content was measured with help of oven by taking leaves from four randomly selected branches, covered in aluminum foil and brought to laboratory, from each treatment for comparison of different irrigation treatment response (Melgar et al., 2008).

Nitrogen, phosphorus and potassium uptake in leaves: Leaves were taken randomly from each treatment from selected branches, washed with distilled water, initially air dried and then dried in the oven at 72ºC for 48 hours, the dried samples were grinded sieved through 2mm mesh and stored in bottles. To record the nutrients, 0.5mg of plant samples were taken in 100mL flask, 10mL concentrated HNO_3as added and kept overnight and then 4mL of concentrated HCl was added. These samples were digested using a hot plate, the samples were filtered in 100mL volumetric flask and the volume was made up to the mark with distilled water. The nitrogen uptake affected by different irrigation depths was determined by existing soil, basal dose (50g $tree^{-1}$ of NPK; 15:15:15%) applied and sample taken from different treated trees using Kjeldhal methods of total nitrogen (Bremner and Molveny, 1982), total phosphorus (Olsen and Sommers, 1982) and potassium was determined by flame-photometer.

Statistical analysis: All data were subjected to statistical analysis for split plot arrangement. The means were compared at 5% probability using MSTAT-C Software.

Main plot-A:	Irrigation depths	Sub-plot:	Cultivars
To	100% of ETo		Bincolilla
T1	80 % of ETo		Leccino
T2	60 % of ETo		Frantoio
T3	40 % of ETo		

RESULTS AND DISCUSSION

Shoot growth rate: The mean monthly growth rate data during the irrigation season (May, June, July, August and September) per irrigation depth applied is presented in Table1. The result showed that different irrigation depths, cultivars differences and their interaction significantly affected the average shoot growth rate of the different cultivars. The different irrigation depths affected the growth rate significantly in most of the cases, the non significant differences were found at the start of experiment in the month of May, while there were significant differences among the growth rate for the rest the time of season. The highest growth rate obtained from controlled irrigation depth applied may be due to proper match of the crop water demand of the plant. As the proper water supplied, met the consumptive demand of the crop., the moisture retention may be for longer period and might have directly affected the availability of water and nutrients to the plants this might be the reason to have ultimately increased the growth rate of the young olive cultivars. The least growth rate which occurred in the remaining irrigation depths applied may be due to inappropriate moisture content for metabolic activities and transportation of minerals. Irrigation amount allows young trees to grow more quickly, Similar results have been obtained by Connor and Fereres (2005) who reported that olive is severely affected by water availability during their early stages. Water is also a chemical agent and can affect plant physiological process up to some extent and ultimately plant growth. Adaptations to water availability also involve changes in plant chemistry. Upon mild and moderate water deficit conditions, photosynthesis decreases in olive plants mainly due to stomata closure (Angelopoulos et al. 1996). However, as the stress progresses, biochemical constraints may limit the photosynthetic CO_2 fixation more directly (Lawlor. 1995). Which help to produce reactive oxygen species (ROS), mainly in the photosynthetic reactive oxygen species, which include singled oxygen, superoxide anion, hydrogen peroxide and hydroxyl radicals, are necessary for the correct functioning of plants and can play a role in inter- and intracellular signaling (Foyer and Noctor, 2000). It was also reported that water supplied by irrigation minimizes the negative effects of water stress on olive performance (Fernandez and Moreno., 1999), probably reducing the oxidative damage at shoot apex, buds and leaf levels. All cultivars showed significant shoot growth rate during experiment. Different cultivars had variable response to different irrigation depths applied. Frantoio had the highest growth rate and that result was expected because Frantoio is rapidly growing cultivar as compared to other cultivars including Leccino (Tongetti et al. 2008), which might indicate the response of the genotype under such conditions, these results are in agreement with those reported by Eryuce and Puskulue (1995) and Jordao et al. (1999), who found that different olive cultivars showed different growth rates although they were treated same. Besides this Moutier (2000) described that differences among cultivars in shoot length and diameter growth is common in young olive plant trees however during the study Bincolilla showed poor performance throughout the experiment which confirm that that was a slow growing cultivar. Shoot growth rate patterns for irrigation depths and cultivars effect interaction, were similar in all the three cultivars with controlled irrigation depths (Figs. 1, 2 and 3). Maximum values were observed in cultivar Frantoio (3.25cm) followed by Leccino (2.79cm), while minimum growth rate was observed in cultivar Bincolilla (2.6cm). No significant differences between treatments were recorded in May, while significant difference was observed at the reaming span of experiment. A progressive gap was recorded between the most and the least irrigated plants the result which agrees with Ahmad et al. (2007).

Table 1. Mean monthly shoot growth rate (cm) of different cultivars affected by different irrigation depths.

	May	June	July	August	Sept.
Irrigation depth					
To	0.8230a	1.334a	1.912a	2.430a	2.880a
T1	0.7920a	1.193b	1.632b	2.041b	2.436b
T2	0.7900a	1.026c	1.436c	1.520c	1.990c
T3	0.7590a	0.886d	1.262d	1.249d	1.583d
$Lsd_{0.05}$	0.072	0.072	0.096	0.196	0.203
Olive cultivars					
Bincolilla	0.772b	1.003c	1.414c	1.519c	1.922c
Leccino	0.786ab	1.075b	1.587b	1.743b	2.121b
Frantoio	0.816a	1.251a	1.681a	2.168a	2.624a
$Lsd_{0.05}$	0.038	0.038	0.047	0.116	0.106

Main plot: Irrigation depths
Sub-plot: Cultivars

Table 2. Mean monthly shoot diameter (cm) of different cultivars affected by different irrigation depths.

	May	June	July	August	Sept.
Irrigation depth					
100%	1.656a	3.567a	5.278a	6.989a	8.633a
80%	1.567ab	3.011b	4.389b	5.858b	7.633b
T60%	1.500ab	2.378c	3.689c	5.022c	6.811c
40%	1.387b	1.911d	2.944d	3.549d	4.633d
$Lsd_{0.05}$	0.233	0.121	0.25	0.268	0.311
Olive cultivars					
Bincolilla	1.392b	2.258c	3.708c	4.925c	6.192c
Leccino	1.567a	2.642b	4.067b	5.233b	6.933b
Frantoio	1.617a	3.250a	4.450a	5.833a	7.658a
$Lsd_{0.05}$	0.122	0.142	0.227	0.289	0.378

Shoot diameter (mm): Data recorded for shoot diameter (thickness) is presented in Table 2 for the month of May, June, July, August and September, respectively. The results revealed that the different irrigation depths had significant effect on shoot thickness. The different irrigation depths affected the shoot thickness significantly. The shoot thickness was no significant during the month of May. However, there were significant differences were observed among the growth rate in the rest of experiment duration. Much difference was observed among most and least irrigated treated plants. Irrigation amount allows young trees to grow more quickly, Similar results have been obtained by Connor and Fereres (2005) who reported that olive is severely affected by water availability during their early stages. Water relations and vegetative development (shoot thickness) were a function of water available to plants (Tongetti et al., 2006).Similar results have been obtained by Magliulo et al. (2003) on the same cultivars and D'Andria et al. (2004) on different cultivars reported that tree size (diameter) is important for modern olive growing, and tuning of irrigation strategies. Besides this, Moutier (2000) described that differences among cultivars in shoot length and diameter growth is common in young olive plant trees. All cultivars showed significant increase in shoot diameter during experiment. Different cultivars had variable response to different irrigation depths application. Frantoio showed maximum increase in shoot thickness and this result is expected because Frantoio is rapidly growing cultivars as compared to other cultivars including Leccino (Tongetti et al., 2006. Bincolilla showed poor performance throughout the experiment. Shoot thickness pattern for irrigation depths and cultivars effect interaction, were almost similar in the whole span of experiment (Figs. 4, 5 and 6). Maximum shoot thickness (9.6mm) was noted for plants of Frantoio cultivar treated with controlled irrigation depth followed by Leccino (8.26mm) and Bincolilla (8mm) it is obvious that shoot thickness decreased as water application amount decreased in respect to some cultivars. Water deficit first affects the vegetative growth (Hsiao, 1973). Its influence on this aspect can result smaller shoot diameter (Michelakis et al., 1994), lower growth of shoot length (Proietti and Antognozzi, 1996; Girona et al., 2000) and of its diameter which causes a lower crown development (Michelakis et al., 1994; Girona et al., 2000) in different olive cultivars.

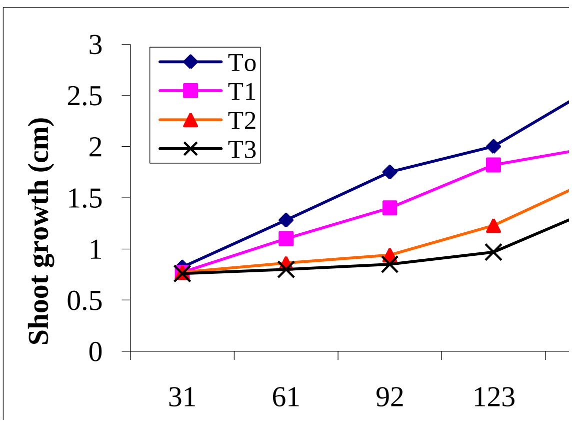

Fig. 1. Effect of different irrigation depths on Bincolilla Cv.'s shoot growth.

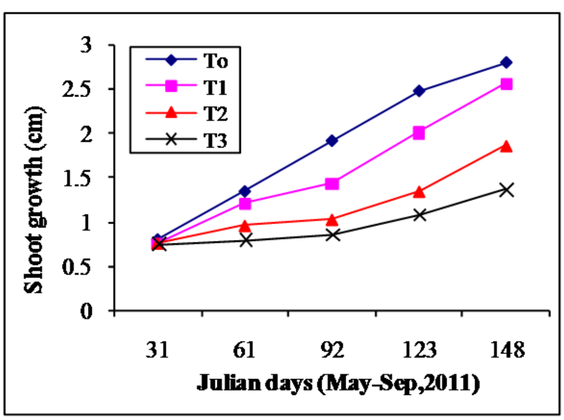

Fig. 2. Effect of different irrigation depths on Leccino Cv.'s shoot growth.

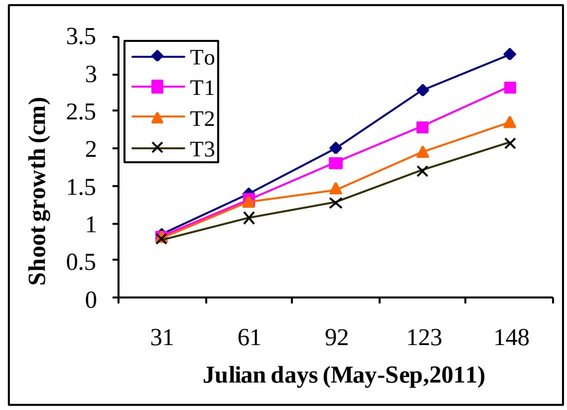

Fig. 3. Effect of different irrigation depths on Frantoio Cv.'s shoot growth.

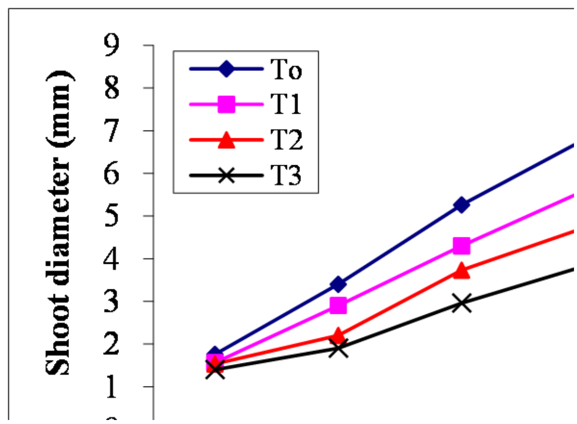

Fig. 4. Effect of different irrigation depths on Bincolilla Cv.'s shoot diameter.

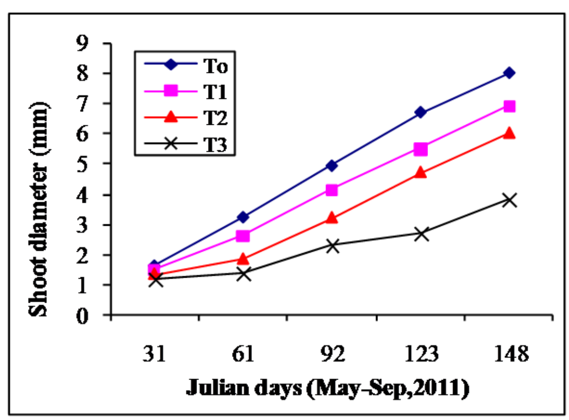

Fig. 5. Effect of different irrigation depths on Leccino Cv.'s shoot diameter.

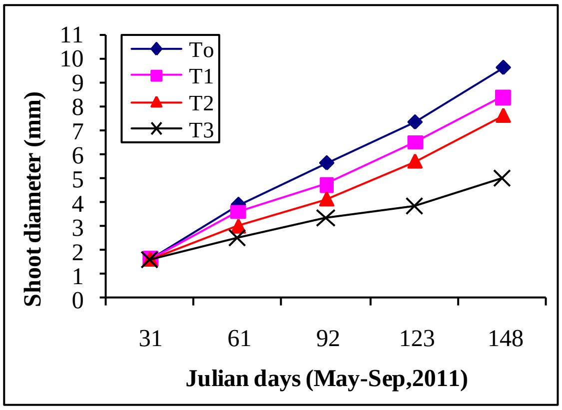

Fig. 6. Effect of different irrigation depths on Frantoio Cv.'s shoot diameter.

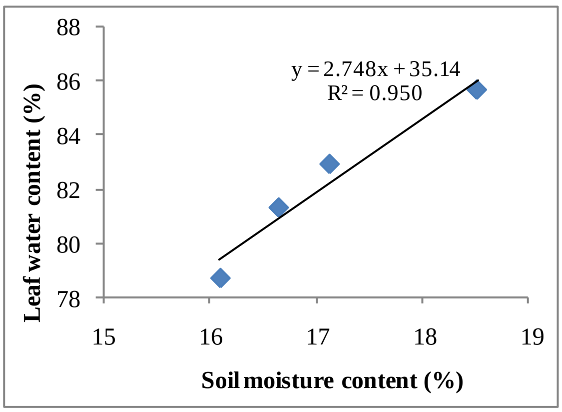

Fig. 7. Regression between SMC and LWC for different irrigation depths on Frantoio cv.

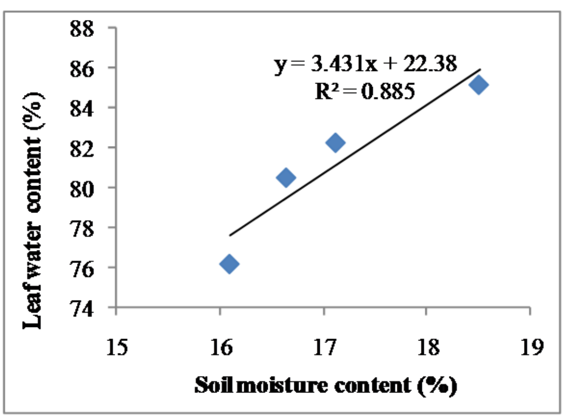

Fig. 8. Regression between SMC and LWC for different irrigation depths on Leccino cv.

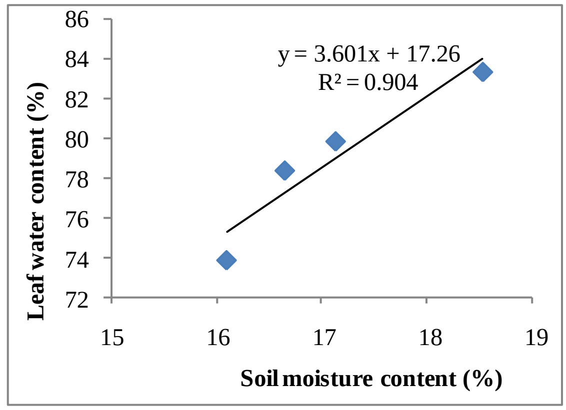

Fig. 9. Regression between SMC and LWC for different irrigation depths on Bincolilla cv.

Leaf area (cm^2): The statistical analysis shows that the different irrigation depths, cultivars and their interaction had no significant effect on the leaf area. The uneven leaf area size may be due to the environmental factor and the adoptability of theses cultivars in the local agro-climatic condition (Jackson, 1981).

Leaf water content (LWC): Leaf water content showed significant variation with different irrigation depths applied. A positive correlation was existed between leaf water content and the amount of water present in the root zone between different irrigation depths and cultivars (Figs. 7, 8 and 9). This result may be due to many factors, one of which is a lack or optimum uptake of water that restricts transpiration, inducing closure of stomata and resulting in less water evaporating from the leaf surface. The results are in agreement with Clearwater and Goldstein (2005) and Lopez et al. (2007) who reported that rapid increase in soil moisture improves the recovery of leaf conductance, therefore part of this recovery may be linked to a large increase in root flow in olive trees while the rate of irrigation depths strongly affects water relations of leaves during the period of recovery in olive young age. Vegetation water status is an indicator of the degree of stress experienced by plants in their environment (Larcher, 1995). Vegetation or leaf water deficit can be defined as any disturbance that adversely influences growth (Jackson et al., 1981).

Nitrogen: The total nitrogen content (TNC) in leaves of all the three cultivars significantly increased with the passage of time. However, with the decrease in irrigation application depth, the uptake was decrease. In the last three months, Frantoio showed more tendency of uptake to all irrigation depths applied as compared to Leccino and Bincolilla (Figs. 10, 11 and 12). Maximum nitrogen uptake was observed in control. However, the trees with other irrigation depths had least leaf nitrogen content as compare to control (Figs. 4, 5 and 6). But in general, all treatments had significant effect on nitrogen uptake upto some extent which could be due to the younger stage of respective plants (one year) which mostly agree with Ferriera (1983) outcomes, who reported that young plants have higher nitrogen up take capabilities. Furthermore, young plants have vigorous growth which demand more nitrogen, hence requires its increased adsorption rate. In addition to that, it is also an essential element for chlorophyll in the plant. Another factor might be the sampling time during the year, as reported by Drassopoulos and Niavis (1998), which effect olive, leaves nitrogen reserves. Obviously, it was cleared that sap transport was greater in plants having more water and ultimately it had carried high amount of N from soil. Experimental results showed that olive plants subjected to water deficit could uptake low nutrients (Lebote et al., 1998) having lower water content and lower water potentials for their tissues, establishing a particularly high potential gradient of TNC, also compromise to the result obtained by Sofo et al. (2008). Irrespective of irrigation depths applied, all cultivars were on the same level of significance for nitrogen up take leading by cultivar Frantoio (1.9%) as compare to other two cultivars Leccino and Bincolilla (1.5% and 1.5%, respectively) with same irrigation depth applied shown in Figures 3, 4 and 5, respectively. Leaf N uptake is in the optimum range as (1.01-2.55%) for 50-200 g per tree as reported by Ferreira (1983). In addition to the environmental conditions, the genetic integrity of the plant species might influence particular nutrient uptake efficiency (Popovic et al., 1999). Moreover, this might indicated the performance efficiency of nutrient uptake and translocation in case of Frantoio under field conditions, in accord to what Tongettie et al. (2006) suggested that Frantoio is the rapid growing cultivar, and can uptake more nutrients as compare to other cultivars treated same for water and nutrient application.

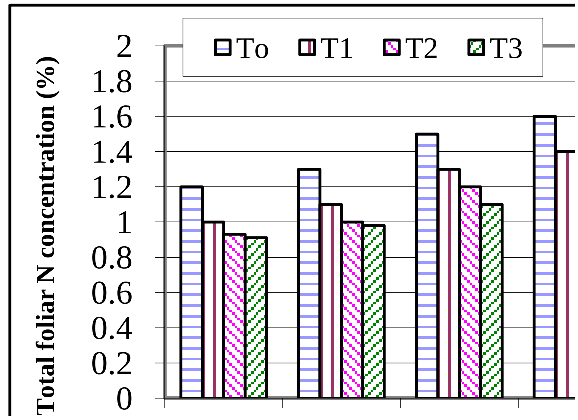

Fig. 10. Total nitrogen concentration effected by different irrigation depths in Frantoio.

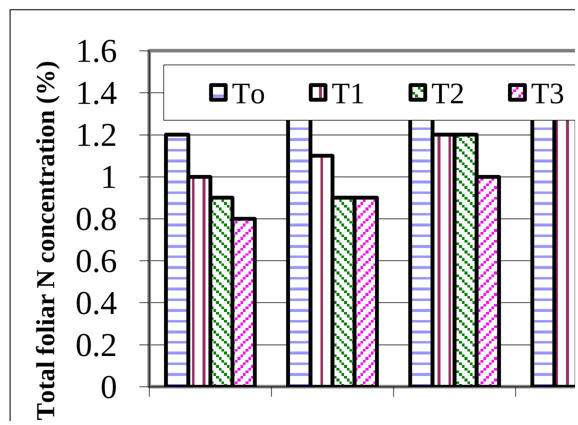

Fig. 11. Total nitrogen concentration effected by different irrigation depths in Leccino.

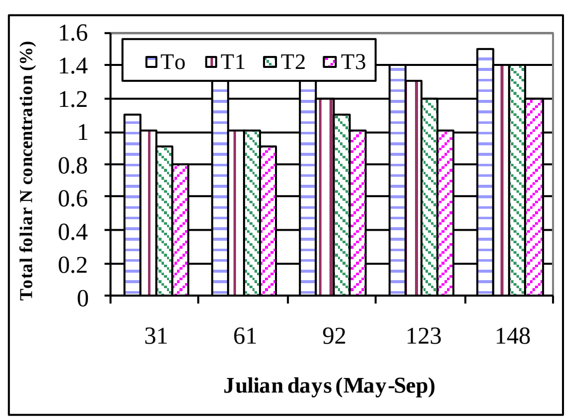

Fig. 12. Total nitrogen concentration effected by different irrigation depths in Bincolilla.

Phosphorus: The total phosphorus concentration (TPC) in the leaves of all the three cultivars Frantoio, Leccino and Bincolilla varied significantly with respect to the different irrigation depths applied, cultivars differences and their interaction. Presenting tendency of same pattern decreased with less water application in all months, although the highest TPC was observed at the end of the experiment. It was due to the accumulation of P in the leaves from the beginning of irrigation season shown in Figurs 13, 14 and 15 respectively. Result indicated that Phosphorus contents in leaves were higher in controlled condition and decreased as the irrigation amount decreased according to different irrigation depths, none of the treated trees had significant increase in leaf P contents over control. Maximum Phosphorus uptake was observed in cultivars Frantoio and Leccino with controlled irrigation depth (0.26 %) followed by Bincolilla with same irrigation depth applied (0.24%), figures 4, 6 and 8 respectively. Leaf P uptake was in the optimum range as (0.05-0.34%) for 50-200 g per tree as reported by Ferreira (1983). However, the trees treated with other irrigation depths had least leaf Phosphorus contents as compare to control. Variation in P uptake could be referred to the weather conditions that might be responsible for this variation since plant will consume energy for thermal regulation and leaves cooling. Therefore, nutrients contents in the leaves of same treatment may vary from time to time. Another factor that might be involved is the amounts and ratios of the nutrients in olive leaves can change depending on variety differences, more or less pruning, and ecological properties, especially soil structure and depth, and climate (Marschner, 1995).

Potassium: The total potassium concentration (TKC) of all the three cultivars Frantoio, Leccino and Bincolilla significantly varied during experiment duration, showing a tendency significantly the effect of different irrigation depths, cultivar differences and their interaction. TKC showed minor fluctuation in its values (Figs. 16, 17 and 18), the foliar TKC was much greater than TPC in all three cultivars with all irrigation depths. It was due to the parent soil having largest amount of potassium. This type of behavior in the tendency of the values of K was observed in Olive by Fernandez et al. (1999). Leaf K content was within the optimum range (0.22-1.65%) for 50-200 g per tree as reported by Ferreira (1983) for olive trees, and suggested that K assimilation start with the beginning of vegetative growth and accumulates in leaves since it's not heavily in demand at this period, but low K content could be related to the harsh weather conditions, since it had been suggested that K effect transpiration rate and participate in leaves cooling. All of the irrigation depths, cultivar differences, and their interaction had significant effect on leaf potassium content. Maximum leaf K content was observed with controlled irrigation depth in Frantoio. This is an accordance with Ferreira (1983) who reported that potassium do accumulates in the leaves, stem and roots of the beginning of vegetative growth in some cultivars, since it is not heavily in demand at this period and may also be partially related to the addition of potassium since high potassium concentration in soil would inhibit K-active transport mechanism in low water conditions or may be dilution effect of nitrogen and related either to the mobility of potassium in soil since the plants were irrigated once a week as reported by Jordao et al. (1999)..

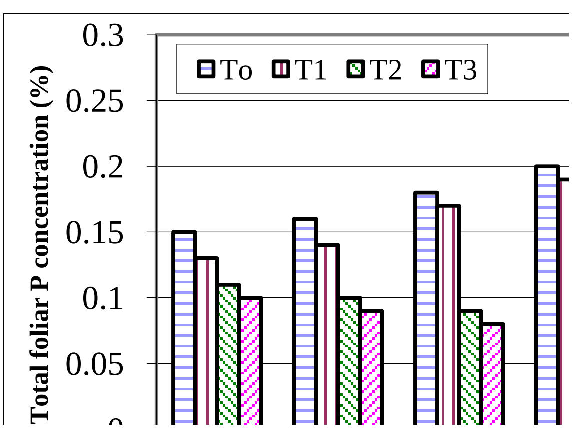

Fig. 13. Total Phosphorus concentration effected by different irrigation depths in Frantoio.

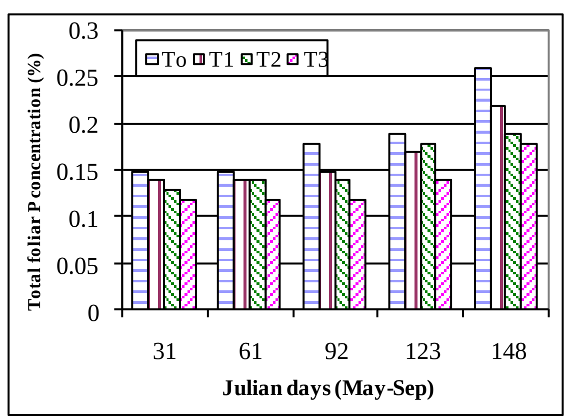

Fig. 14. Total Phosphorus concentration effected by different irrigation depths in Leccino.

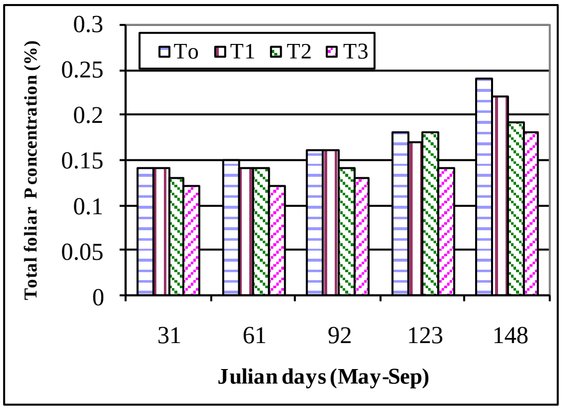

Fig. 15. Total Phosphorus concentration effected by different irrigation depths in Bincolilla.

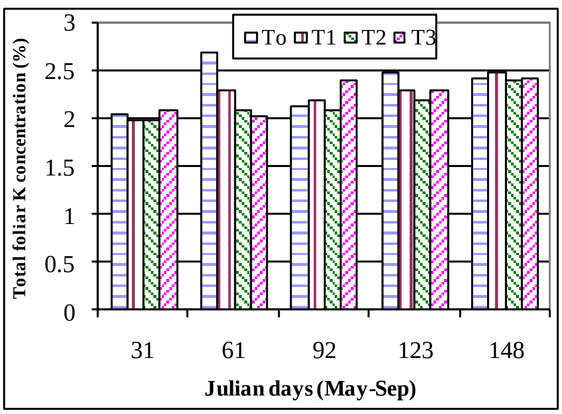

Fig. 16. Total Potassium concentration affected by different irrigation depths in Frantoio.

CONCLUSIONS

During the study it was concluded that:

- The applications of low water doses under same environmental conditions affected growth parameters (shoot length and shoot diameter) appropriately.
- The different irrigation depths affect leaf water contents in olive plants. During the study period leaf water contents showed a clear response to the soil water status. The changes caused by different irrigation treatments, confirm their great sensitivity to the irrigation regime.
- On the basis of cultivar's differences Frantoio is highly responsive to different irrigation depths

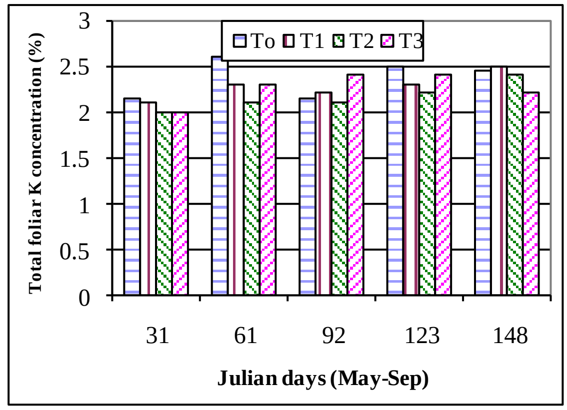

Fig. 17. Total Potassium concentration affected by different irrigation depths in Leccino.

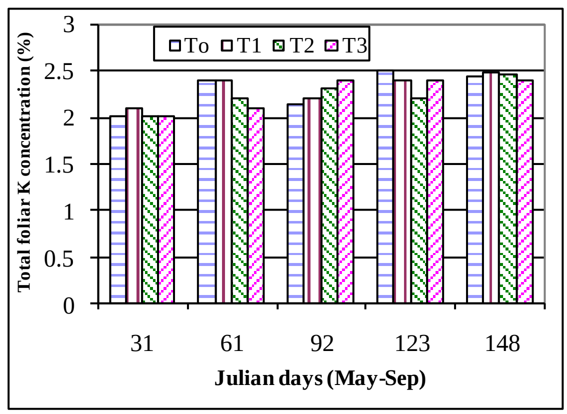

Fig. 18. Total Potassium concentration affected by different irrigation depths in Bincolilla.

and showed highest growth rate as compare to Leccino and Bincolilla.

- Different irrigation depths significantly affected NPK uptake, as much as cultivars concerned the Frantoio is more capable for nutrients up taking.

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