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Influence of Nutrients on Growth, Fruitfulness and Leaf Nutrient Status of Olive (*Olea europaea* L.)

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Abstract

The anomalous and clogged uptake of nutrients and scrimpy soil fertility status were the main factors, which accounts for poor growth and yield of olive trees. Accordingly, olive trees of these areas exhibit a sublime response to foliar application of nutrients like Nitrogen, Potassium, Boron and Zinc in emboldening flowering and fruit set of olive. Keeping this in view, a field experiment was carried out during 2004-6 to infer the influence of nutrients on growth, fruitfulness and N, P, K, status in olive. The experiment consists of different treatments i.e. 0.5% Nitrogen (N), 0.5% Boric Acid (H_3BO_3), 0.5% Zinc Sulphate ($ZnSO_4$) and their amalgamations were given. Significantly higher shoot extension growth (6.09 cm) and leaf area (6.23 cm^2) in olive, were observed in 0.5% N. Bloom intensity (0.58%) and fruit set (6.69%) were found significantly higher under 0.5% H_3BO_3,+0.05% $ZnSO_4$. Foliar application of 0.5%N has also culminated in a higher stomatal size (17.95×11.35 μm^2), whereas a transcendent increase in stomatal density was recorded with control (79.84). Nitrogen content was perceived maximum under 0.5% N (1.72%), P (0.179%) and K (1.68%) content was found utmost under H_3BO_3 0.5%. The present investigation has evinced that application of 0.5%N was most efficacious in inducing optimum vegetative growth whereas, application of 0.5% H_3BO_3+0.5%$ZnSO_4$ was most effectual in enhancing bloom intensity, perfect flowers and fruit set in olive. Foliar application of Boron and Zinc can aid in escalating foliar Zinc and Boron level in olive trees, which in turn plays their role in pollination, fertilisation and increased fruit set of olive trees.

Keywords: Olive, zinc sulphate, stomatal density, foliar application

1. Introduction

The olive (*Olea europaea* L.) is an evergreen tree but requires chilling for fruiting and it is mostly grown for oil extraction that holds numerous biological and medicinal values. An erratic trend of monsoon and winter rains has become more conspicuous in the last decade which further aggravated the problem of poor growth and bearing in olive trees. The inconsistent and restricted uptake of nutrients and lower soil fertility status were other factors, which also account for poor growth and yield of olive trees. Olive's nutrient requirements are lower than that for many other fruit trees, but shortage in these requirements costs the tree major physiological disorder (Freihat et al., 2006). Therefore, olive trees of these areas have shown a spectacular response to foliar application of nutrients like nitrogen, potassium, boron and zinc. Urea is considered as an ideal carrier of N and has a considerable effect on growth, flowering and fruit set in olive (Frega et al., 1995). Which, stimulates translocation of N from leaves to inflorescence and then to growing fruits. Jasrotia et al. (1999) also found a significant increase in olive productivity with increasing nitrogen doses. Foliar application of boron and zinc can help in increasing foliar Zn and boron level in olive trees, which further plays their role in pollination, fertilisation and in turn, increased fruit set of olive trees (Bybordi and Malakout 2006). Boron and zinc application alone or in combination tended to decrease the formation of shoot berries, reduced the extent of fruit abscission during the period initial and final fruit set (Nyomora et al., 1999). Boron application increases fruit set and yield in several fruit and nut crops, including almond, filbert, Italian prune and sour cherry (Hanson, 1991). Foliar spraying zinc sulphate and boric acid one week before full bloom leads to an increase in fruit set and yield of olive. Foliar application of micronutrients is a valuable practice; against the micronutrient deficiency curing micronutrient deficiency through foliar application is a common practice in getting profitable yield and good quality fruit (Khawaga, 2007). Foliar spray is advantageous over soil application because of rapid responses, effectiveness and elimination of deficiency symptoms due to certain micronutrients (Sheikh et al., 2007; Gimenez et al., 2001). Hence, the present study was undertaken to improve the productivity of olive trees by appropriate manipulation of their nutrient and physiological status.

2. Materials and Methods

The present investigation was conducted at the experimental orchard of Department of Fruit Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, India (30°20' North latitude, 77°11' East longitude, altitude 1240 MSL) and falls under under the mid hill zone of Himachal Pradesh, where summers are moderately hot (35–38 °C). The winter season is experienced between the months of December to February. However, maximum rainfall is received during the month of June to September, whereas, light winter showers are experienced during the months of January to March. The average annual rainfall of the area ranges from 1000–1300 mm. The trial was laid out with eight treatments on two olive cultivars viz., Leccino and Frantoio in a randomised block design and replicated thrice. Uniform, healthy and disease free trees of 17 years of age were selected. The entire technical programme as envisaged in 8 treatments viz., Nitrogen (0.5%), Zinc sulphate (0.5%), Boric acid (0.5%), Nitrogen (0.5%)+zinc sulphate (0.5%), Zinc sulphate (0.5%)+Boric acid (0.5%), Boric acid (0.5%)+Nitrogen (0.5%), Nitrogen (0.5%)+Zinc sulphate (0.5%)+Boric acid (0.5%), Control (Water sprays+surfactants). Two foliar sprays were given at one week before flower bud differentiation and 25 days before beginning of flowering.

Twenty-five healthy uniform shoots of previous season's growth were selected on all sides of the tree covering entire periphery to record observation of shoot extension growth, relative growth rate, leaf area and stomatal density. The length of each shoot was measured at the beginning and end of growing season to determine shoot extension growth. Relative growth rate was determined by the recording new shoot extension growth occurred by the entire growing season time to time. Leaf area was determined by using leaf area meter, LI-COR Model-3100. Stomatal density and stomatal size were done with the method suggested by Beaulieu et al. (2008). The stomata size was recorded with the help of Leica Stereoscopic Microscope. The blooming intensity of experimental trees was recorded in accordance with formulae suggested by Westwood. For the ascertaining proportion of perfect flowers, twenty-five inflorescences have sampled all sides of the experimental trees. The individual flowers of these inflorescences were carefully examined to determine their sex i.e., perfect and staminate on the basis of presence or absence of a fully developed and functional pistil. The observations on the fruit set were recorded at two weeks after petal fall and then were again confirmed at six weeks after full bloom so as to allow sufficient time for the abscission of unfertilized parthenocarpic fruits. In order to estimate the leaf nutrient status, leaves with petioles were sampled in mid-August from the middle portion of the current season's shoot situated all around the periphery of the tree. The dried samples were then ground and stored in butter paper bags for chemical analysis. Potassium, calcium and magnesium in the leaf extract were estimated on Perkins Elmen Atomic Absorption Spectrophotometer.

3. Results and Discussion

The data presented in Table 1 revealed that foliar application of N, $ZnS0_4$ and H_3BO_3 has shown its significant effect on shoot extension growth of olive trees and among different treatments, maximum shoot extension growth (6.09 cm)

Table 1: Effect of nitrogen, zinc sulphate, boric acid and their combinations on growth characteristics of olive

Treatments	Growth (cm)			Relative growth rate (cm^{-1} cm^{-1} $month^{-1}$)			Leaf area (cm^2)		
	Leccino	Frantoio	Mean	Leccino	Frantoio	Mean	Leccino	Frantoio	Mean
N (0.5%)	6.06	6.13	6.09	0.066	0.070	0.068	6.53	5.92	6.23
$ZnS0_4$ (0.5%)	3.67	4.23	3.95	0.047	0.048	0.048	5.38	4.69	5.04
H_3BO_3 (0.5%)	4.81	5.24	5.03	0.054	0.063	0.059	5.83	5.27	5.55
N (0.5%)+$ZnS0_4$ (0.5%)	4.33	4.83	4.58	0.052	0.049	0.051	5.77	4.97	5.37
H_3BO_3 (0.5%)+$ZnS0_4$ (0.5%)	3.93	4.61	4.27	0.049	0.048	0.049	5.69	4.76	5.23
H_3BO_3 (0.5%)+N (0.5%)	4.70	5.11	4.90	0.057	0.062	0.060	6.49	5.50	5.99
N (0.5%)+$ZnS0_4$ (0.5%)+H_3BO_3 (0.5%)	5.02	5.44	5.23	0.060	0.068	0.047	6.15	4.41	5.78
Control	3.54	4.05	3.80	0.046	0.047	0.047	5.36	4.56	4.96
Mean	4.51	4.05		0.054	0.057		5.90	5.13	
CD (p=0.05)									
T			0.21			0.003			0.70
C			0.11			0.001			0.35
TXC			NS			NS			NS

was observed in treatment comprising of 0.5% N, which was followed by 0.5% N+0.5% $ZnSO_4$+0.5%H_3BO_3 (5.23 cm) whereas the least value of shoot extension growth (3.80 cm) was recorded under control. It was also evident that between two olive cultivars, Significantly higher growth (4.95 cm) observed in Frantoio in comparison to Leccino but interaction between treatments and cultivars were found non-significant This increase in growth characters might be in view of the fact that nitrogen is an integral part of chlorophyll, which leads to higher photosynthetic efficiency (Fernandez et al., 2009). These observations are also in conformity with the findings of Bybordi and Malakouti, 2006, who have also reported that application of nitrogen-containing fertilisers increases tree growth in olives. All treatments applied have shown a significant increase in relative growth rate of treated trees. However, maximum relative growth rate (0.068 cm^{-1} cm^{-1} $month^{-1}$) was recorded in treatment 0.5% nitrogen followed by 0.5% N+0.5% $ZnSO_4$+0.5% H_3BO_3 (0.064 cm^{-1} cm^{-1} $month^{-1}$). The minimum value of relative growth rate was observed under control (0.047 cm^{-1} cm^{-1} $month^{-1}$). It was further observed that significantly increased relative growth rate (0.057 cm^{-1} cm^{-1} $month^{-1}$) recorded in cultivar Frantoio, whereas treatment cultivar interaction was non-significant. The data given in Table 1 also indicated highest value of leaf area (6.23cm^2) was observed in treatment of 0.5% N, which was statistically at par with treatments comprising of 0.5% H_3BO_3+0.5%N (5.99 cm^2), 0.5% N+0.5% $ZnSO_4$+0.5% (5.78 cm^2), whereas, recorded minimum (4.96 cm^2) under control. Between two olive cultivars, significantly more leaf area (5.90 cm^2) was observed in Leccino and the treatment cultivar interaction was found to be non-significant. These results are in accordance to those of Garcia et al. (1994). Yet, in the present studies, the foliar applications of H_3BO_3 and $ZnSO_4$ were observed to have less effect on various growth parameters. In fact, the foliar applications of H_3BO_3 alone or $ZnSO_4$ in combination with each other were similar to the control in respect of various growth parameters but their effects were more pronounced only when combined with nitrogen. Therefore, nitrogen seems to be most important factor in enhancing the vegetative growth and the beneficial effect of nitrogen on growth promotion, may be because of its involvement in cell division, as a constituent of amino acids, proteins, nucleic acid and enzymes. Although growth regulating effect of zinc is also reported by various research workers (Sandhu et al., 1994; Lal et al., 1998) yet it failed to increase the overall growth of olive trees in the present studies. The less effect of zinc on growth might be due to the occurrence of water stress conditions. These differences between plants growth characteristics might be due to inherent characteristics of Leccino and Frantoio.pe. The highest stomatal density (79.84) was observed (Table 2) under control, which was statistically at par with 0.5% H_3BO_3+0.5% $ZnSO_4$, 0.5% $ZnSO_4$, 0.5% N+0.5% $ZnSO_4$ but the remaining treatments were also statistically at par with control. However, minimum stomatal density was observed in 0.5% nitrogen and control. The data further revealed that between two olive cultivars, Frantoio had significantly higher stomatal density (81.37) than Leccino. There were non-significant differences among different treatments and cultivars. Result of the study in Table 2 also revealed that stomatal size was significantly influenced by different treatments and the highest value of stomatal size (17.95×11.34 μm^2) was observed in 0.5% N, which was statistically at par with treatments comprising of

Table 2: Effect of nitrogen, zinc sulphate, boric acid and their combinations on stomatal characteristics of olive

Treatments	Stomatal size (µm)						Stomatal density (No.)		
	Length			Breadth					
	Leccino	Frantoio	Mean	Leccino	Frantoio	Mean	Leccino	Frantoio	Mean
N (0.5%)	17.90	17.99	17.95	11.38	11.31	11.35	74.00	80.00	77.00
$ZnS0_4$ (0.5%)	15.72	16.68	16.20	10.27	10.17	10.22	76.33	82.67	79.50
H_3BO_3 (0.5%)	17.03	17.70	17.36	11.04	11.09	11.08	75.00	81.00	78.00
N (0.5%)+$ZnS0_4$ (0.5%)	16.58	17.03	16.80	10.52	10.61	10.57	75.33	81.33	78.33
H_3BO_3 (0.5%)+$ZnS0_4$ (0.5%)	16.16	16.94	16.55	10.17	10.52	10.35	76.00	82.00	79.00
H_3BO_3 (0.5%)+N (0.5%)	16.59	17.47	17.03	10.61	11.02	10.82	74.33	80.67	77.50
N (0.5%)+$ZnS0_4$ (0.5%)+H_3BO_3 (0.5%)	17.47	17.65	17.56	10.48	11.19	10.84	74.00	80.33	77.17
Control	15.71	16.59	16.15	10.15	10.04	10.10	76.67	83.00	79.84
Mean	17.52	17.26		10.69	10.74		75.21	81.37	
CD (p=0.05)									
T			0.94			0.57			1.60
C			NS			NS			0.80
TxC			NS			NS			NS

0.5% N+0.5% $ZnSO_4$+0.5% H_3BO_3 (17.56×11.33 μm²); 0.5% H_3BO_3 and 0.5% $ZnS0_4$+0.5%H_3BO_3+0.5% N (167.03×10.81 μm²) whereas remaining treatments were statistically at par with control. It was apparent from the Table 2 that both the cultivars and treatment cultivar interaction effects have failed to show any significant differences pertaining stomatal size. The present findings have also shown inconspicuous and minor changes in stomatal size and density of two olive cultivars. These characters seem to have been influenced by genetic constitution of the plant and hence were not much affected by nutrient treatment Jasrotia et al. (1999).

It was quite apparent from the data presented in Table 3 that bloom intensity, the proportion of perfect flowers and fruit set of olive cultivars were significantly influenced by the foliar application of different nutrients. Thus maximum bloom intensity (0.58%) was recorded in 0.5% $ZnSO_4$+0.5% H_3BO_3. This treatment was statistically superior to all other treatments. Among remaining treatments, bloom intensity in 0.5% H_3BO_3, to 0.5% N was statistically at par with that of 0.5% N. However, the minimum value of bloom intensity (0.48%) was observed in control. Leccino (0.54 %) had higher bloom intensity than Frantoio, yet both were statistically at par with each other. The interaction between treatment and cultivars were also found non-significant. Maximum value of the proportion of perfect flowers (59.17%) was recorded in the treatment comprising of 0.5% $ZnSO_4$+0.5%H_3BO_3. But the remaining treatments were statistically at par with one another but these were superior to control. Between cultivars studied, significantly highest proportion of perfect flowers (55.93%) was observed in Frantoio, thus it appears to be more fruitful compared to Leccino. The interaction between cultivars and treatment was found to be non-significant. Thus all treatments have shown their profound impact in increasing the proportion of perfect flowers in olive trees which, might be attributed to faster translocation/mobility of these nutrient in treated leaves to the shoot apices or potential flora buds, in turn, thus enhanced level of these nutrients prevailed in developing floral buds, which have stimulated the process of ontogeny in such buds and thereafter, contributed for increasing the proportion of complete or bisexual flowers. These results are in agreement with the findings of Talaie and Taheri, 2001; Perica et al., 2002. Among different treatments, maximum fruit set (6.69%) was observed in treatment comprising of 0.5% $ZnSO_4$+0.5% H_3BO_3 followed by 0.5% H_3BO_3 and 0.5% N+0.5% $ZnS0_4$, respectively. But all these treatments were significantly different from each other. Among remaining treatments, 0.5% N+0.5% $ZnSO_4$+0.5% H_3BO_3 and 0.5% N were statistically at par with each other. Whereas, remaining treatments including control were statistically inferior to these two treatments. The data in Table 3 further indicated that between two olive cultivars higher fruit set (5.94%) was recorded in Leccino than in Frantoio. The interaction of treatment and cultivars was found non-significant. The proper development of pistil and its associated organs might have played its role in increasing the extent of fruit set by possibly increasing the "effective pollination period" (EPP) of olive cultivars. The increase in bloom intensity and fruit set of olive cultivars as evidenced in present studies might be due to an apparent mobility of boron at all developing stages of olive growth and the translocation of boron to developing tissues as was also postulated by Perica et al. (2002); Nyomora et al. (1999). The higher fruit set obtained in above treatments somehow relate to boron metabolism, carbohydrate transfer and hormonal metabolism which contributed for optimum nutrient content in the plant

Table 3: Effect of nitrogen, zinc sulphate, boric acid and their combinations on fruiting characteristics of olive

Treatments	Bloom intensity (%)			Proportion of perfect flower (%)			Fruit set (%)		
	Leccino	Frantoio	Mean	Leccino	Frantoio	Mean	Leccino	Frantoio	Mean
N (0.5%)	0.56	0.54	0.55	54.80	58.40	56.60	5.92	3.59	4.76
$ZnS0_4$ (0.5%)	0.53	0.52	0.53	52.53	56.20	54.37	5.12	3.62	4.37
H_3BO_3 (0.5%)	0.52	0.53	0.53	54.00	55.90	54.95	6.97	4.73	5.85
N (0.5%)+$ZnSO_4$ (0.5%)	0.54	0.53	0.54	54.80	57.73	56.27	6.27	4.01	5.14
H_3BO_3 (0.5%)+$ZnSO_4$ (0.5%)	0.58	0.58	0.58	59.70	58.63	59.17	8.10	5.28	6.69
H_3BO_3 (0.5%)+N (0.5%)	0.56	0.56	0.56	54.27	56.53	55.40	5.13	3.38	4.25
N (0.5%)+$ZnS0_4$ (0.5%)+H_3BO_3 (0.5%)	0.51	0.52	0.52	52.40	54.57	53.48	6.03	3.81	4.92
Control	0.49	0.47	0.48	49.70	49.50	49.60	3.95	2.76	3.36
Mean	0.54	0.53		54.02	55.93		5.94	3.90	
CD (*p*=0.05)									
T		0.01			1.99			0.09	
C		NS			0.99			0.04	
TxC		NS			NS			NS	

which resulted in higher fruit set (Talaie and Taheri, 2001). The olive plants also require additional amounts of boron and zinc to attain optimum fruit set by prolonging the period of ovule longevity and thus increasing the duration of effective pollination period (EPP). The differences in cultivar level might be due to inherent characteristics of the plant. In our findings, a significantly higher fruit set in treatments of H_3BO_3+$ZnSO_4$ may be attributed to enhanced levels of boron in the plant following this treatment which caused transfer of boron from leaves to active inflorescence and changed the competition from leaves to inflorescence and flower and then resulted in a higher fruit set (Frega et al., 1995). Among two cultivars, higher fruit set was recorded in Leccino than in Frantoio, which might be due to differences in their growth and vigor status.

The data (Table 4) indicated that among the different treatments maximum value of N (1.72%) was observed in leaves of olive trees treated with 0.5%N followed by 0.5% N+0.5% $ZnSO_4$+0.5% H_3BO_3 and 0.5% H_3BO_3+0.5% N, respectively. But all these treatments were significantly different from one another and also possessed significantly higher levels of nitrogen when compared to control. The data further indicated that olive cultivar Leccino had significantly higher levels of N (1.63%) than in Frantoio, interaction between treatments and cultivars were found non–significant. This increase in leaf N content might have occurred by faster translocation of nitrogen to the shoot apices of growing points of the tree and consequently, its accumulation took place in the floral buds. The present findings are in line with the findings of Perica et al. (1994); Marcelo et al. (2002). The maximum value of leaf P content (0.179%) was observed in trees where 0.5% N+0.5% $ZnSO_4$+0.5% H_3BO_3 and 0.5% H_3BO_3 alone was applied, which was significantly higher than remaining treatments. Foliar content of both the cultivars have also shown significant differences at cultivar level and leaf P was observed maximum (0.177%) in cultivar Leccino than in Frantoio, whereas interaction between treatments were found non-significant. The other notable treatments, which have also shown an increase in foliar P levels in olive trees, included 0.5%$ZnSO_4$ and N (0.5%), respectively. Leaf phosphorus content decreased with the application of nitrogen, this could be possibly due to the phenomenon of antagonism between phosphate and nitrate ions as also reported by Taheri and Talaie (2001) in olive trees. A perusal of the data (Table 4) reveals that, among different treatments, the highest value of leaf K (1.68%) was observed in 0.5% H_3BO_3 followed by 0.5% N and 0.5% H_3BO_3+0.5% $ZnSO_4$ in decreasing order, respectively. All treatments with the exception of 0.5% H_3BO_3 and 0.5% N were statistically at par with one another in respect of their foliar K content. The leaf K content has also shown significant differences at cultivar level and olive cultivar Leccino possessed significantly higher value of leaf K content (1.59%) than Frantoio. Among two cultivars higher values of N, P and K in Frantoio might be due to differences in their growth. The interaction effect was found to be non-significant between cultivars and treatment. The increased level of K in olive trees treated with 0.5% boric acid might be attributed to higher metabolic activity viz., carbohydrates, nucleic acid, amino acids and protein synthesis, which caused increased dry matter production, resulting in increasing water and nutrient uptake from soil. These observations are in agreement with those of Taheri and Talaei (2001) in olive.

Table 4: Effect of nitrogen, zinc sulphate, boric acid and their combinations on leaf nutrient status of olive

Treatments	Leaf N content (%)			Leaf P content (%)			Leaf K content (%))		
	Leccino	Frantoio	Mean	Leccino	Frantoio	Mean	Leccino	Frantoio	Mean
N (0.5%)	1.76	1.67	1.72	0.180	0.160	0.170	1.67	1.53	1.60
$ZnS0_4$ (0.5%)	1.52	1.39	1.46	0.185	0.164	0.175	1.58	1.53	1.56
H_3BO_3 (0.5%)	1.59	1.48	1.54	0.189	0.170	0.179	1.71	1.64	1.68
N (0.5%)+$ZnS0_4$ (0.5%)	1.63	1.51	1.57	0.165	0.147	0.156	1.49	1.44	1.46
H_3BO_3 (0.5%)+$ZnSO_4$ (0.5%)	1.55	1.43	1.49	0.174	0.156	0.165	1.60	1.55	1.58
H_3BO_3 (0.5%)+N (0.5%)	1.70	1.58	1.64	0.166	0.148	0.157	1.51	1.46	1.49
N (0.5%)+$ZnS0_4$ (0.5%)+H_3BO_3 (0.5%)	1.71	1.61	1.66	0.180	0.178	0.179	1.57	1.52	1.55
Control	1.61	1.36	1.43	0.170	0.150	0.160	1.56	1.52	1.54
Mean	1.63	1.50		0.177	0.158		1.59	1.52	
CD (*p*=0.05)									
T			0.02			0.002			0.05
C			0.01			0.001			0.02
TxC			NS			NS			NS

4. Conclusion

Application of 0.5% N was most efficacious in inducing optimum vegetative growth whereas application of 0.5% H_3BO_3+0.5% $ZnSO_4$ was most effectual in enhancing bloom intensity, perfect flowers and fruit set in both the olive cultivars. Foliar application of Boron and Zinc can aid in escalating foliar Zinc and Boron level in olive trees, which in turn plays their role in pollination, fertilisation and increased fruit set of olive trees.

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