EFFECT OF DIFFERENT BORON CONCENTRATIONS AND APPLICATION TIMES ON THE PRODUCTION OF OLIVE (*OLEA EUROPEA* L.)

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ABSTRACT: *A study on the effect of different boron concentrations and their application times on the production of olive (Oleaeuropea L.) was conducted at Cereal Crop Research Institute (CCRI), Pirsabak, Nowshera, during the year 2016. The experiment was laid out in randomized complete block design (RCBD) with two factors in split plot arrangement, and replicated three times. Four concentrations of boron (0, 200, 400 and 600 ppm) were applied as foliar sprays to Olive cultivar Manzanillo at three different growth stages (Pre-bloom, full-bloom and fruit set). Data were recorded for variables such as number of flowers panicle^{-1}, percentage of perfect flowers, number of fruits panicle^{-1},fruit yield plant^{-1}, number of fruits plant^{-1}, percent fruits drop, single fruit weight, size, percent flesh, percent stone and percent oil. Maximum fruit yield plant^{-1} (96.7 kg), and fruit drop (59.3 %) were recorded at pre-bloom stage, whereas maximum single fruit weight (5.6 g), fruit size (5.2 ml), flesh percentage (76.9 %) and minimum fruit stone percentage (23.1 %) were observed when boron was applied at fruit set stage. In case of different boronconcentrations maximum number of flowers panicle^{-1}(15.0), perfect flowers (59.3 %), number of fruits panicle^{-1}(4.0), fruit yield plant^{-1} (89.7 kg),fruit weight (6.4 g), fruit size (5.8 ml), fruit flesh (78.4 %), oil (12.4 %) and minimum stone (21.6 %) was recorded at 600 ppm foliar spray.The overall resultsbrevealed that 600 ppm boron foliar application at pre-bloom stage improved fruit yield plant^{-1}and number of fruits plant^{-1}and at fruit set stage increased fruit weight, fruit size, fruit flesh and oil percentage.*

Key words:Olive, Boron, Growth stages, Manzanillo, fruit set, olive Oil.

INTRODUCTION

Olive (*Oleaeuropea*L) belongs to family Oleaceae, with more than 25000 varieties around the world. Olive was cultivated in 4800 BC in Mediterranean region. However, it is widely cultivated in central Asia, various parts of Africa, Australia and North and South America as well [1]. It is reported that the present day olive is derived from hybridization and mutation [2]. Olive is an evergreen plant with grey-green or silver, thick and hard leaves that are arranged in opposite direction to each other. The leaves are replaced at 2-3 years interval with new growth that appears in spring [3]. Olive inflorescence develops at the axil of each leaf, which has 15-30 flowers. There are two types of flowers in olive, perfect and staminate. The pistil and stamen are well developed in perfect, while only functional stamens are developed in staminate flowers. Both self and cross pollination are experienced in olive flowers with help of wind [4].Olive fruit is a drupe, oval in shape that remains green during the development process till the maturity and contains active chloroplast that helps in the process of photosynthesis, fruit development and oil production [5]. Olive oil is the healthiest edible oil that is a rich source of unsaturated fatty acids, energy, vitamins and Oleuropein that contains free radicals, having scavenging properties. Olive oil can be used for lowering the incidence of cancer and cardiovascular diseases [6].The worldwide olive oil consumption has increased upto 73% over the last 25 years, that encourages the producers to increase quality and quantity. But there is a problem of relatively low boron contents in most of the soils. Only soluble boron in soils is available for plants and this is usually about 10% of the total soil boron content. The occurrence of boron deficiency depends on multiple factors, mainly caused by the reduction of the availability of soluble boron in the soil, weather conditions (drought, high precipitation), boron leaching, calcareous soils and the cultivated crop species. Plants absorb boron from the soil as borate, a negatively charged ion (anion) while at Low pH boron react chemically with the soil particles and are "tied up" in forms that are unavailable to plants. Boron deficiency causes reduced pollen production and poor fruit set in the generative organs of olive plant. Sensitivity to boron deficiency varies among varieties as well [7]. To recover boron deficiency foliar boronspray is considered to be a fast and target oriented method. Foliar absorption from liquid solutions may take place via cuticle, cuticular cracks and imperfections, through stomata, trichomes or specialized epidermal cells. Two mechanisms of foliar absorption have been discussed and characterized to a certain extent, namely, the cuticular pathway and the stomatal pathway [3].The present study was carried out to improve the productivity and quality of olive fruit by foliar boron application at appropriate growth stage.

MATERIALS AND METHODS

An experiment was conducted to see the ffect of different boron concentrations and their application times on the production of olive at CCRI Pirsabak, Nowshera, Pakistan during the year 2016. The experiment was carried out in randomized complete block design (RCBD) with two factors in a split plot arrangement that were replicated three times. Boron application at growth stages i.e. pre-bloom, full-bloom and fruit set were kept in the main plots, while organic boron concentration i.e. 0. 200. 400 and 600 ppm were kept in sub plot.Olive Trees were exposed to organic boron (6% elemental boron) foliar application. The trees received the recommended fertilizer rates (N, P, K). All other farm practices were kept constant for all the experimental units throughout the growing season. The data were recorded on the following parameters.

Number of flower panicle^{-1}:

Number of Panicleswere selected randomly from each plant. The number of flowers counted on each panicle and their means were calculated.

Number of flowers panicle^{-1} $=\frac{Total\ Number\ of\ flowers}{Number\ of\ panicles}$

Perfect flower percentage:

Olive flowers were observed at full bloom stage for staminate and perfect flower and then tepercentage of perfect flowers was calculated as;

Percent of perfect flowers = $\frac{Number\ of\ perfect\ flowers}{Total\ Number\ of\ flowers} \times 100$

Number of fruits panicle^{-1}:

Panicles were selected randomly from each plant, and counted the number of fruits on each panicle then average was calculated.

Number of fruits panicle^{-1}= $\frac{Total\ Number\ of\ fruits}{Number\ of\ Panicles}$

Fruit yield plant^{-1} (kg):

Fruits were collected from each plant manually and weighed. Average yield plant^{-1} was calculated for each treatment.

Fruit drop percentage:

Fruit drop percentage was measured with the following formula.

Fruit drop percentage

$=\frac{Initial\ fruits\ \mathbf{panicle}-1 - Final\ fruit\ \mathbf{panicle}-1}{Initial\ fruits\ paniclespike-1}\times 100$

Fruit weight (g):

Fruits were taken from each treatment, weighted and then average was calculated.

Fruit weight (g) $=\frac{Weight\ of\ fruits}{Nnmber\ of\ fruits}$

Fruit size (ml):

Fruit size was determined by using water displacement (Scale cylinder) method.100 ml graduated cylinder was filled with water up to 50 ml, then fruit was put in the cylinder that raise the volume and the fruit size was calculated by subtracting the initialreading from final reading.

Fruit flesh (%):

Each fruit was weighed by the stone, then stone we 2 separately and subtracted from fruit weight and ------ percentage was calculated.

Fruit flesh (%) $=\frac{Fruit\ weight - Stone\ weight}{fruit\ weigh}\times 100$

Fruit stone (%):

Each fruit was weighedby the stone, then flesh weighed separately and subtracted from fruit weight and stone percentage was calculated with the following formula.

Fruit stone (%) $=\frac{Fruit\ weight - fruit\ flesh\ weight}{fruit\ weight} \times 100$

Fruit oil percentage:

Oil was extracted from 30 kg fruit sample of each treatment at teAgriculture Research institute (ARI)Tarnab oil extraction unit. The fruit oil percentage was calculated by using the following formula.

Fruit oil percentage $=\frac{\mathbf{oil\ extracted}\ (\mathbf{lit})}{\mathbf{fruit\ sample}}\times 100$

Statistical Analysis: The data recorded for different variables were subjected to Analysis of Variance (ANOVA) techniqueto observe the differences between the different treatment as well as their interactions [8]. In cases where the differences were significant, the means were further assessed for comparison through Least Significant Difference (LSD) test. Statistical computer software, Statistix 8.1, was used for computing both the ANOVA and LSD.

RESULTS AND DISSCUSION

Number of flowers panicle^{-1}

Data regarding number of flowers panicle^{-1}table 1 revealed that foliar application of boron levels significantly affected the number of flowers panicle^{-1} of olive. Maximum number of flowers panicle^{-1} (15.0) were produced by the plants that were sprayed with 600 ppm boron, while minimum (9.0) flowers panicle^{-1}were produced by control plots.As boron plays an important role in improving calcium mobility, sugar transport and flowering hormone regulation, boron foliar application is needed to enhance olive flowering[9]. Confirmed that foliar boron application significantly increased the developing olive flowers, fruits, and growing shoots[10]. Also reported that boron foliar application successfully maximized the number of flowers panicle^{-1}[11].

Perfect flowers percentage

Data in table 1 showed that perfect flowerspercentage were significantly increased in response to the boron foliar application. With the increase of boron concentration the percentage of perfect flowers also increased up to a maximumof (59.3 %) at 600 ppm.Whileminimum perfect flowers (52.0 %) were noted in control plots.Boron is an essential micro-nutrient, olive tree need adequate amounts of boron for flower fertility, pollen viability, pollen germination and pollen tube growth[7]. Foliar boron spray is an effective method for improving growth and perfect flower production[12]. Plant response dependent upon fertilizer form, concentration, application time and plant growth stage.

Number of fruits panicle^{-1}

Result in table 1 showed a significant increase in the number of fruits panicle^{-1} in response to boron foliar application comparing with control plots. The higher boron dose (600 ppm)was increased number of fruits panicle^{-1} up to (4.0). While minimum fruits panicle^{-1} (2.0) appearing on plants that were not treated with boron. Boron feeding is essential to improve fruit yield and quality of olive [13]. It has an important role in cell wall strengthening, cell division, sugar transport and hormone regulation. Adequate boron nutrition is critical for high yield and quality of olive [7]. It is alsoreported that boron application significantly improved fruit set, fruit yield and fruit quality of olive[14].

Fruit drop percentage

The fruit drop percentage was significantly affected table 2 by boron application at different growth stages and the boron concentrations had no effect. The interaction between growth stages and boron levels was not significant. The results showed that minimum fruit drop (53.5%) was recorded for plants that received boron spray during fruit set, whereas maximum fruit drop (59.3%) was observed in plants that received boron spray in pre-bloom stage. Current study showed that boron application at pre-bloom stage improved fruit yield plant^{-1}, so fruit load was heavier as compared to the plants that were sprayed during fruit set stage. As there was a high fruit load on the plants that received boron treatment in pre-bloom stage. This probably caused more fruit drop as these plants received the same amount of water and nutrients as the other treatments and the plants were unable to withstand the heavy load. These results are in line with [14] who reported that the fruit drop was a natural way to reduce heavy fruit load due to the competition among the developing fruits for food, water, and nutrients. This natural thinning removes excess fruit and allows the remaining fruit to develop properly.

Table 1: Influence of different concentrations of boron on number of flowers panicle^{-1}, perfect flowerpercentage and number of fruits panicle^{-1}of olive cultivar Manzanillo.

Boron	Number of flowers panicle^{-1}	Perfect flower percentage	Number of fruits panicle^{-1}
0	9.00 b	52.00 b	2.00 b
200	12.70 ab	57.00 ab	3.00 ab
400	13.30 a	58.60 a	3.30 a
600	15.00 a	59.30 a	4.00 a
LSD values	**3.67**	**5.77**	**1.28**

Fruit yield plant^{-1} (kg)

Data in table 2 showed that boron application at different growth stages and different boron concentrations significantly affected fruit yield plant^{-1} of olive. However, the interaction between boron applied at different stages and different boron concentrations was also significant.Interaction between boron and growth stages indicated that the application of 600 ppm boron, at pre-bloom stage increased yield plant^{-1} (104 kg) but declined to 91.3 kg at full bloom stage. However, control plants were observed with minimum yield plant^{-1} (68.3 kg) at fruit set stage. The demand for boron as an essential nutrient is more in reproductive growth as compared to vegetative growth[15]. In our current study, foliar application of boron at high concentration at pre-bloom stage considerably increased fruit yield. The increase in fruit yield may be because of boron on increase fruit set via increase pollen viability or pollen tube growth and flowering hor[illegible] regulation[16]. Decrease in fruit yield when sprayed [illegible] bloom could be due to flower drop due to high spray pressure[17].

Fruit size (ml)

The data in table 2 showed that fruit size was significantly affected by boron levels and its applications at different growth stages. The interaction between boron applied at different stages and different boron concentrations was non-significant. Maximum fruit size (5.2 ml) was recorded in plants that received boron at fruit set stage, whereas the minimum (4.2 ml) was recorded in plants that received boron at pre-bloom stage. Similarly, maximum fruit size (5.9 ml) was obtained from plants that were treated with 600 ppm boron foliar applications. While minimum fruit size (3.7 ml) was found in control plots. Boron has an important role in cell wall strengthening, cell division, sugar transport and hormone regulation. Adequate boron nutrition is critical for yield and quality of olive[7]. It is reported that the increase in yield and fruit size is due to increase in photosynthetic capacity and improvement in source strength[10].

Fruit weight (g)

The data pertaining to fruit weight of olive are given in table 2, indicated that fruit weight was significantly affected by boron concentrations and its applications at different growth stages. The interaction between boron applied at different stages and different boron concentrations was non-significant.Maximum fruit weight (5.6 g) was recorded for plants that received spray during fruit set, whereas minimum fruit weight (4.5 g) was observed in plants that received boron spray at pre-bloom stage. Regarding different boron concentrations, maximum fruit weight (6.3 g) was achieved from plants that were treated with 600 ppm boron foliar applications. While minimum fruit size (4.1 g) was obtained from control plots.Boron has a critical role in cell wall formation, stabilization, lignification and xylem differentiation. It is required to ensure normal development of new tissues from roots to flowers and fruit[18].The increase in fruit weight may be due to the increased absorption of boron and water, resulting in more photosynthesis and increased nutrients accumulation in fleshy parts of fruits, That results in increaseof olive fruit weight[9][17.

Table 2: Influence of different concentrations of boron, applied at different growth stages on fruit yield plant^{-1}, fruit size and fruit drop (%) of olive cultivar Manzanillo.

Growth stages	Fruit yield plant^{-1} (kg)	Fruit size (ml)	Fruit drop (%)
Pre-bloom	96.6 a	4.2 b	59.3 a
Full-bloom	81.6 a	4.4 b	55.0 ab
Fruit set	73.3 c	5.2 a	53.5 b
LSD α 0.01	**2.95**	**0.32**	**4.36**
Boron concentrations (ppm)			
0	76.4 c	3.7 c	56.4
200	83.1 b	4.2 bc	56.4
400	86.3 ab	4.6 b	55.3
600	89.6 a	5.8 a	55.5
LSD α 0.01	**4.67**	**0.53**	**NS**
Interaction	**8.09**	**NS**	**NS**

Table 3: Influence of different concentrations of boron, applied at different growth stages on fruit weight, fruit flesh, fruit stone and oil percentage of olive cultivar Manzanillo

Growth stages	Fruit weight (g)	Fruit flesh (%)	Fruit stone (%)	Oil (%)
Pre-bloom	4.5 b	75. 3 ab	24.7 ab	11.3
Full-bloom	4.7 b	74.0 b	26.0 a	11.3
Fruit set	5.6 a	76.9 a	23.1 b	10.9
LSD α 0.01	**0.54**	**1.93**	**3.7**	**NS**
Boron concentration				
0	4.0 c	73.0 b	27.0 a	10.2 c
200	4.5 bc	74.7 b	25.3 a	10.7 bc
400	4.8 b	75.6 ab	24.4 ab	11.2 b
600	6.4 a	78.4 a	21.5 b	12.4 a
LSD α 0.01	**0.61**	**3.7**	**1.93**	**0.71**
Interaction	**NS**	**NS**	**NS**	**NS**

Fruit flesh (%)

The data in table 2 showed that fruit flesh (%) was significantly affected by boron concentrations and its applications at different growth stages. The interaction between boron application at different

stages and different boron concentrations we non-significant. Maximum fruit flesh (76.9 %) was recorded for plants that received boron spray during fruit set, whereas minimum fruit flesh (74.0 %) was observed in plants that were sprayed in full bloom stage. Similarly, te maximum fruit flesh percentage (78.4 %) was obtained from plants that were treated with 600 ppm boron foliar application. While minimum fruit flesh percentage (73.0 %) was obtained from control plots. Boron is an essential trace element for plants that improves fruit weight by increasing size and flesh with accumulation of more food[11].Also found that foliar boron application significantly increased the fruit flesh percentage[17].

It is suggested that the increase in fruit flesh may be due to the increase in absorption of boron and water, resulting in more photosynthesis and increased nutrient accumulation in ye fleshy parts of fruits[9].

Fruit stone %

The data pertaining to the fruit stone percentage of oli 4 given in table 2, indicated that fruit stone was signific affected by boron concentrations and its applications at different growth stages**.** The interaction between boron application at different stages and different boron concentrations was non-significant.Minimumfruit stone percentage (23.1 %) was recorded for the plants that received spray during fruit set, whereas maximum (26.0 %) was observed in plants that were sprayed at full bloom stage. As well, minimum fruit stone (21.6 %) was obtained from plants that were treated with 600 ppm boron foliar applications. While maximum fruit stone (27.0 %) was obtained from control plots.In this study, foliar application of boron at high concentrations resulted smaller stone fruits as compared to the lower concentrations. On the other hand, the results of this study showed higher fruit flesh % at higher boron concentrations. Our current findings suggests that plants utilized most of their energy for development of fruit flesh rather than fruit stone.The fruit stone % was decreased with the increase in flesh %, with boron application[17].

Olive oil %

The data in table 2 indicated that tolive oil percentage was significantly affected by different boron concentrations. While boron applications at different growth stages and the interaction between growth stages and boron were found non-significant.Maximum olive oil (12.4 %) was extracted from the plants that were treated with 600 ppm boron as a foliar spray. While minimum fruit oil (10.2 %) was extracted from control plots. A great increase was found in olive oil content due to boron treatments[19]. Boron foliar spray has a positive impact on oil accumulation of different olive cultivars. Boric acid boosted oil content in the fruits which were significantly higher than untreated fruits[20].

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