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Improvement of mango (*Mangifera indica* L.) fruit quality and yield using boron foliar application

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This study was undertaken to investigate the role of foliar application of boron for improvement of mango fruit quality and yield. A field experiment was conducted during two successive seasons 2014/2015 and 2015/2016 using fifteen years old mango (*Mangiferaindica* L.) trees cv. Zebda. Foliar treatments included three boron concentrations of 0.0, 250 and 500 mgL^{-1} applied as boric acid in January. Results show that boron foliar application significantly improved fruit quality (size, weight, firmness, color, total acidity, total soluble solid (TSS), total sugar and vitamin C) and increased fruit yield relative to the control. Fruit chemical characteristics show a reduction in total acidity but an increase in total soluble sugars and vitamin C content. Fruit physical characteristics show reduction in fruit size, fruit weight, fruit firmness and improvement in fruit color as the boron application rate increase. Fruit yield significantly increased at 250 mg $L^{-1}$of boron. Boron application in the off year have increased C/N ratio which resulted in an increase in flower percentage, final fruit set, number of fruit/tree and fruit yield.

Keywords: Mangiferaindica L., fruit yield, fruit quality, boron, off year.

INTRODUCTION

Mango (*Mangiferaindica* L.) is of great economic importance fruit crop in Egypt. The area planted with mango have increased until it reached 111 hectare which produce 8.33 ton per hectare according to the Ministry of Agriculture and Land Reclamation statistic (2014). Mango cultivars particularly cv. Zebda is low in fruit productivity due to several reasons such as alternate bearing (Shaban, 2009). El-Shamy et al. (1990) found that regardless of the mango cultivar, there was a significant difference in the average yield between the trees in the on-year and those in the off-year. On year refer to a year of heavy yield but off year is a year of light one (Monselise and Goldschmidt, 1982). Foliar spray of boric acid significantly increased fruit yield and improved fruit physical and chemical properties of apple trees (Khalifa et al. 2009). The effect of boron on yield can be attributed to the increase in percentage of perfect flowers and fruit retention (Perica et al. 2001).

Boron has a major role on fruit quality as well as yield potential in mango (Raja *et al*. 2005). The improvement in fruit quality may be due to more sugar translocation from leaves to developing fruits as sugar-borate complex is more easily transverse the membrane (Singh et al. 2009). Whereas, Anees et al. (2011) suggested that the enhancement in fruit quality could be due the catalytic action of micronutrients which increase the uptake of macronutrients by mango plants, decrease the nutritional deficiencies and improve fruit quality. Boron is very effective in increasing

ascorbic acid content in mango (Singh *et al.* 2003). VishWakarma et al. (2006) showed an enhancement of mango productivity as a result of boron application. In addition, boron application has improved mango fruit quality in term of fruit weight, total soluble solid, total sugars and coloration (Rashmi and Singh, 2007). Singh *et al.* (1987) found a significant increase in total soluble solids and total sugars of mango fruit due to application of different concentrations of boric acid to mango trees. Boron in mango has been reported to be the agent for reducing acidity (Dutta, 2004). Such effects of boron might be due to its enhancement on pollen germination, pollen tube growth, carbohydrates and protein metabolism and sugar transport within the plant (Marschner, 1995).Consequently, such effects lead to high fruit set and yield. The objective of this research is to increase mango fruit quality and yield in the off year using foliar application of boron.

MATERIALS AND METHODS

Boron foliar application was performed in January using fifteen years old mango (*Mangiferaindica*) trees cv. Zebda grown at AlMalak Valley Farm, El-Sharkeya Governorate, Egypt (30-51^{o} N; 32-53^{o} E). The experiment was conducted for two successive seasons 2014/2015 and 2015/2016.The trees were planted 8x8 meters apart in sandy soil under drip irrigation system using the Nile water. Boron was applied, the off year, as boric acid at the following concentration (0.0, 250 and 500 mgL^{-1}). Tween 20 was added to the foliar solution at 1ml/L rate. The control trees were sprayed with deionized water.

The chemical and physical properties of the soil were determined according to (Dewis and Freitas, 1970 and Johnson and Fixen, 1990) and are shown in Table (1).Treatments were arranged in Completely Randomized Block Design with three replicates. Two-way analysis of variance was performed according to (Steel and Torrie, 1960) using MSTAT statistical microcomputer program. Significance between treatments means was compared using LSD at 5% probability (Snedecor and Cochran, 1980).

Evaluation of Fruit Quality

Fruit quality was assessed by the physiochemical analysis of the following parameters:

Physical characteristics:

1-Color, mango fruit external color was evaluated using the Chroma Meter CR-400, Konica Minolta Sensing, Inc. Japan; firmness (g/cm^{2}), using the Penetrometer, Fruit Pressure Tester, Italy; weight of whole fruit(g), using balance; size (cm^{3}), using cylinder

Chemical characteristics:

Chemical analysis was conducted on fresh fruit juice. Fruits were peeled and flesh was homogenized in a blender. Total soluble sugars, according to (Dubois et al. 1956); total acidity, was measured and calculated as percentage citric acid according to the (A.O.A.C., 1984); total soluble solids (TSS), using portable hand re fractometer, Germany; vitamin C, was determined according to the (A.O.A.C., 1984). Leaves were collected one month after boron application (in February). Leaf samples were washed with deionized water, oven dried at 70 ^{o}C for 24 hours until a constant weight is reached. Total carbohydrate was determined according to (Herbert et al. 1971).Total nitrogen was determined using Kjeldahl method according to (Jones et al. 1991).

Yield determination:

Fruits were collected at maturity stage in August. Each individual tree was harvested manually and the number of fruits/tree was counted. Yield was estimated by multiplying the number of fruits/tree x average fruit weight.

Table (1): The chemical and physical properties of the soil.

Depth	Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Texture class	pH	EC (dS/m)	Organic matter (%)	TCC (%)	BD (g/cm^{3})	N (%)	Boron (mg.kg^{-1})	
												Total	Available
0-25	67.9	28.9	1.88	1.25	Sandy	7.56	0.34	1.55	13.0	1.64	0.07	19.7	1.01
25-50	63.5	33.1	2.05	1.36	Sandy	7.81	0.30	1.00	15.0	1.95	0.05	19.1	1.07

RESULTS

Fruit quality characteristics:
Physical Parameters:
Fruit external color

Table (2) show an increase in lightness (L) values as the boron application rate increased compared with the control. This indicates that boron has enhanced color development of mango fruit and reduced darkening. The control treatment (zero boron) showed the lowest L values indicating darker color than boron treated fruits. The chroma (C) values of the mango fruit increased as the concentration of boron increased compared to the control. Mango fruit developed more vivid coloration as the boron application rate increased. The hue angle (h) values decreased as the concentration of boron increased compared to the control. This indicate that boron have a role indeveloping the specific color of Zebda cultivar.

Fruit weight

Results in Table (2) indicate that fruit weight has significantly decreased as the concentration of boron increased for the two seasons compared with the control. The highest fruit weight was recorded at the control treatment. The results disagree with (Stino et al. 2011) who found an increase in weight of mango fruit after spraying with boric acid at 2000 mgL^{-1}.

Fruit size

Results in Table (2) show significant reduction in fruit size as the boron concentration increased comparing with the control for the two seasons. The largest fruit size was recorded at the control treatment but the smallest fruit size was observed at 500 mg L^{-1} concentration. The results disagree with (Hegazi et al. 2015) who found a significant increase in olive fruit size in response to boron foliar application compared with the control. In this study the reduction in fruit size in response to boron foliar application may be due to high fruit set and high number of fruit/tree.

Fruit firmness

Results in Table (2) show that mango fruit firmness significantly decreased as the boron concentration increased compared with the control, for the two seasons. Fruit firmness recorded 34 for the control, 32 for 250 mg L^{-1} and 29.5 kg/cm^2 for 500 mg L^{-1} treatment. Mango fruit firmness was significantly higher in the control treatment comparing with boron treatments. Our results agree with (Stinoet al. 2011) who found a reduction in firmness in mango fruits as a result of boron spray compared with the control. High fruit firmness in the control was reported by (Elkhishen, 2015) and may be due to the low number of fruits per tree.

Fruit yield

Results in Table (3) show that fruit yield, in the off year, significantly increased in response to boron application relative to the control for the two seasons. The increase was significantly higher at 250 mgL^{-1} than at 500 mgL^{-1} boron rate. Figure (1) show the polynomial regression between mango fruit yield and boron application rates indicating a high R^2 (=1) value. Thus, yield correlate strongly with boron application rate. The reduction in yield at higher boron rate, 500 mgL^{-1}, could be due to boron toxicity to pollen grain (Pedoet al. 2005). The increase in fruit yield at 250 mgL^{-1} boron application rate is due to the increase in flower, initial fruit set and final fruit set percentage (data not shown). Our results agree with (Khalifa et al.2009) in apple and (Larbi et al. 2011 and Hegazi et al. 2015) in olive. Although fruit weight decreased as the boron application rate increased, fruit yield increased. This is due to the increase in number of fruit/tree as shown in Table (3)

C/N ratio

Results in Table (3) show that C/N ratio of leaf significantly increased as the boron application rate increased relative to the control, in the two seasons. Boron application in the off year has increased C/N ratio and total soluble sugars which resulted in increasing flower percentage, final fruit set (data not shown), number of fruit/tree and fruit yield. Our results agree with (Elkhishen, 2015).

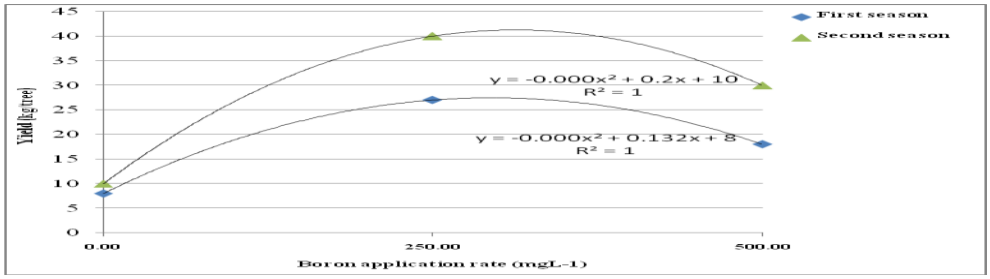
Table (2): Effect of boron treatment on physical characteristics of mango fruit.

Treatment Boron (mg.L^{-1})	Size (cm^3)	Weight (g/fruit)	Firmness (Kg/cm^2)	Color		
				Lightness	Chroma	Hue angle
	First Season (2015)					
0.0	650	660	33.2	48.9	20.9	128.2
250	585	593	31.5	50.1	23.1	126.5
500	569	578	29.2	51.2	24.0	123.7
LSD (0.05)	1.89	1.56	1.16	0.03	0.06	0.18
Second Season (2016)						
0.0	558	562	34.5	47.8	19.1	127.8
250	508	513	32.5	49.2	21.4	125.9
500	456	502	29.8	50.6	24.0	123.0
LSD (0.05)	1.92	1.20	1.06	0.20	0.11	0.21

Table (3): Effect of boron treatment on fruit yield, number of fruit per tree and C/N ratio.

Boron treatment (mg.L^{-1})	Total yield (Kg/tree)	Number of fruit/tree	C/N ratio
	First season (2015)		
0.0	8.0	12	8.48
250	27.0	46	9.21
500	18.0	31	12.11
LSD (0.05)	0.78	2.08	0.063
	Second season (2016)		
0.0	10.0	17	8.15
250	40.0	77	8.97
500	30.0	59	11.39
LSD (0.05)	0.79	1.97	0.077

Figure (1): Polynomial regression between mango fruit yield and boron application rates.



Chemical Parameters:

Total soluble solids

Results in Table (4) show significant increase in mango fruit TSS in response to boron foliar application comparing with the control for the two seasons. Our result is in the same line with (Rashmi and Singh, 2007; Dutta, 2004; Abd-Allah, 2006) who found that boron application has improved mango fruit TSS%. Sugars are the main constituents of total soluble solids. Boron facilitates sugar transport (Marschner, 1995) which may be the reason for increasing fruit TSS.

Total acidity

Results in Table (4) show that total acidity significantly decreased as the boron concentration increased for the two seasons compared with the control. The acidity values recorded 1.50, 1.10 and 0.72 for the control, 250 and 500 mgL^{-1} boron concentrations. The reduction in mango fruit acidity due to boron application is 36% and 97 %

for 250 and 500 mgL^{-1} boron rates, respectively. Boron has been reported as an agent for reducing acidity in mango fruits (Dutta, 2004).

Vitamin C

Results in Table (4) indicate a significant increase in ascorbic acid content as the boron concentration increased comparing with the control for the two seasons. The increase in ascorbic acid was higher than the control by 34% and 51% (average of two seasons) for 250 and 500 mgL^{-1} boron rates, respectively. The increase in ascorbic acid content in mango fruits, in response to boron application, might be due to the increase in sugars (Negiet al. 2009).

Total soluble sugars

Results in Table (4) show significant increase in mango fruit total soluble sugars content as the boron concentration increasedcompared with the control for the two seasons. The results agree with (Rath et al. 1980) and (Singh et al. 1987) who found tremendous increase in total sugars of mango fruit as a result of boron application. The increase in sugar content could be due to rapid translocation of sugars from leaves to developing fruits. The mechanism of such rapid translocation of sugar under boron application was explained by (Dugger, 1983 and Singh et al. 2009) who proposed that, borate reacted with sugar to form sugar-borate complex which is more easily transported within the plant (able to transverse membrane).

Table (4): Effect of boron treatment on chemical characteristics of mango fruit.

Boron treatment ($mg.L^{-1}$)	Total acidity(%)	TSS (%)	Total soluble sugar($mg\ kg^{-1}$)	Vitamin C (Mg/100mlfruit juice)
	First Season (2015)			
0.0	1.66	9.83	953	15.60
250	1.19	10.80	1228	20.50
500	0.72	11.43	1439	23.13
LSD (0.05)	0.063	1.01	1.21	0.22
Second Season (2016)				
0.0	1.34	10.00	950	15.10
250	1.00	11.40	1225	20.70
500	0.72	12.60	1436	23.30
LSD (0.05)	0.03	1.05	1.03	0.20

CONCLUSION

Boron proves to have a major role in increasing leaf C/N ratio and mango fruit yield. Boron application showed beneficial effect on improving fruit quality (e.g. improving coloration, increasing TSS, sugars and vitamin C and reducing acidity). Fruit yield is highly correlated with boron concentration. The best boron treatment that achieved the highest yield is 250 mgL^{-1}, applied in January, in the off year.

CONFLICT OF INTEREST

The present study was performed in absence of any conflict of interest.

AUTHOR CONTRIBUTIONS

All authors contributed equally in all parts of this study.

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