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Effect of foliar boron applications on yield and quality of Medjool date palm

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Abstract

Effects of foliar boron (B) application as H_3BO_3 on yield and fruits quality of date palm (*Phoenix dactylifera* L. var. Medjool) were investigated. The experiment was conducted on 15 years old trees during 2017 growing season. Five different B levels (0, 400, 800, 1200 and 1600 ppm) were applied in a solution of 20 liters·tree^{-1} at three equal doses in May, June and July. Fruit yield and quality parameters were determined at maturity harvest stage (tamer). The results showed that foliar B significantly affected yield, bunch weight, fruit set, fruit physicalcharacters and fruit quality. Boron application at the rate of 1600 ppm resulted in 27 % increase in fruits yield (67.7 vs. 53.4 kg·tree^{-1}), 16 % increase in fruit fresh weight and flesh weight (22.0 vs. 18.9 g.fruit^{-1}), (20.9 vs. 18.0 g fruit^{-1}), respectively, fruit size (49.97 vs. 45.3 mm) and fruit set (88 % vs. 81 %) compared to control. However, the lower rate of boron (400 ppm) was more effective in enhancing fruit quality indices. Total soluble solid (Brix % 75.0), fruit firmness (5.56 kg·cm^{-2}), glucose content (43.17 %), fructose content (39.28 %) and fruit antioxidant activity (80 %) were significantly increased as compared to control. On other hand, date syrup pH, fruit density and fruit skin separation were not affected by boron application. Overall, the results presented here recommended the use of foliar rates of boron ranging between 400 to 1600 ppm to enhance fruit yield and quality in Medjool dates.

Key words: Boron, foliar fertilizer, *Phoenix dactylifera* L, scavenging activity, fruit firmness, reducing sugar, skin separation.

Introduction

Date palm (*Phoenix dactylifera* L.), belongs to the family Arecaceae which is one of the oldest tree cultivated by man 5000 years ago (Vayalil, 2012), and native to harsh semiarid and arid environment where high temperatures, drought and salinity limited the success of other plant species (Altahat, 2015). Date palm cultivation is spread over mainly in Southwest Asia and North Africa (Al-Farsi *et al*., 2008) and still supply food and other valuable product (Vayalil, 2012).

World production of dates has increased from about 4.60 million tons in 1994 to around 8.46 million tons in 2016 to meet the increase in world demand (FAOSTAT, 2017). Jordan Valley is considered one of the best areas for date palm cultivation in Jordan because of its climate advantage (Abu-Qaoud, 2015). Date production became one of the greatest choices for farmers in Jordan valley in the last few years. Today, there are about 484.2 thousand date palm trees as reported in 2016 of which only 225.7 thousand trees are at production stage with a total production of 25.2 thousand metric tons (DOS, 2016). Although, there are several cultivars grown in Jordan such as Barhi, Khadrawy, Khalas, Deglet Noor, Zaghloul, Hayany, Zahidi, Mektour, and Ahmar Talal, 'Medjool' became the dominant cultivars in Jordan with about 300 thousand trees which equal 62 % of total date tree in Jordan. This is due primarily to the high commercial value of Medjool fruits as compared to other cultivars. Jordan ranked globally 22nd for total dates production and 15th for Medjool dates worldwide (FAOSTAT, 2017). Medjool trees produce soft fruits with large size and orange-yellowish flesh (Elhoumaizi *et al*., 2006), and consumed mainly at the Tamer stage with low moisture levels. In addition to fruit properties such as size, taste, sugar content and agro-mechanical properties (Lobo *et al*., 2013; Gophen, 2014), Medjool fruits quality is also affected by skin separation of ripe fruits which reduces the commercial value of this cultivar (Gophen, 2014; Lustig *et al*., 2014). Skin separation levels above 10 % disqualify fruits for export and lower its value (Lustig *et al*., 2014). Improving fruits quality is a significant concern to dates producers for the economy of this cultivar.

Earlier studies on date fruits quality improvement focused on many agricultural practices like pollination (Shafique *et al*., 2011), fruit thinning (Awad, 2006; Al-Sekhan, 2009; Soliman and Al-Obeed, 2011; Soliman and Harhash, 2012), irrigation (Carr, 2013) and fertility managements (Chao and Krueger, 2007). Soil application of macro and micro nutrient fertilization increased dates production and improved fruits quality (Al-Rawi, 1998; Yahia and Kader, 2011). But soil nutrient uptake is affected by soil texture (El-Nour, 2002). pH (Wear and Patterson, 1962), concentration and availability of other nutrients (Hallmark and Barber, 1984), soil moisture (Hanway and Scott, 1957; Barber, 1985), root morphology and absorption capacity (Nye, 1966), which result in reduced availability for plant growth especially during increased demand stages that coincides with fruit setting and development. This drew attention to foliar application of nutrients, especially micronutrients, as an alternative or supplementary method (Mengel, 2001). Many previous studies reported the importance of macro and micronutrients foliar application in enhancing yield and quality of date palm fruits (Elsabagh, 2012; Esam *et al*., 2016). Boron is an essential micronutrient for plants (Goldberg, 1997) which was reported to be more important during plant reproductive growth stages (Brown and Shelp, 1997). Boron was also reported to have critical role in cell wall synthesis and membrane integrity in addition to nucleic acid, carbohydrate and protein metabolism (Goldbach, 1997) and sugars transport in plants (Gauch and Dugger, 1953). Further effects on chlorophyll pigments (Thurzo *et al*., 2010), up regulation of photosynthetic enzyme activity like ribulose-1, 5-bisphosphate carboxylase/oxygenase (Rubisco) (Han *et al*., 2008) and oxidative stress enzymes (Tewari *et al*., 2009) are also reported. Positive effects of boron were reported on improving fruit set, fruit yield and quality of different dates cultivars (Khayyat *et al*., 2007; Harhash and Gr Abdel-Nasser, 2010; Elsabagh, 2012; Sarrwy *et al*., 2012; Rasmia *et al*., 2015). In Jordan which is the third biggest producer of Medjool dates, according to Jordan Dates Association (JODA) the low quality of dates fruit caused annual losses reaching 40 million JD.

The main objective of this study was to explore the benefit of using micronutrient like Boron as foliar fertilizer in improving Medjool date palm yield and fruit quality

Materials and methods

Study site: The study was carried out at the University of Jordan, Agricultural Research Station located in the central Ghor area (Damia region), 35’35’49.69 longitude and 32’05’23.93 latitude, and 265 m altitude. This area is characterized by an arid Mediterranean climate with minimum and maximum temperatures ranged from 27 to 54 °C, respectively and minimum and maximum relative humidity ranged from 38 %-to 76 % (Fig. 1). The mean annual precipitation in 2016-2017 growing season was about 202 mm which is lower than the long term average (281mm). The average reference monthly evapotranspiration ranged from 2 mm /day in January to 7.8 mm in July. Soil of the study area was sandy clay loam/loam (Table 1).

Plant materials and treatments: Fifteen healthy and uniform Medjool date palms trees (15-years-old) were selected for this study. All trees were manually pollinated from the same male tree source (Medjool cv). Drip irrigation system was used to supply trees with an average of 3 $m^3 \cdot tree^{-1}$ per week from day 7 after pollination (mid of April) until the end of July. In August (Khalal stage Fig. 2,) irrigation water supply was reduced into 0.5 $m^3 \cdot tree^{-1}$ per week until the beginning of rutab stage at which irrigation water was ceased.

Table 1. Soil analysis of experiment field at the University of Jordan Research Station, Jordan Valley, Jordan, 2017

Parameter	Soil depth (cm)	
	0-30	30-60
pH	7.6	7.3
EC (dS/m)	2.77	3.97
$CaCO_3$ (%)	31	29
Total N (%)	0.025	0.05
Total P (ppm)	153	111.6
Available K (ppm)	281	359
Organic matter (%)	1.2	1.25
Boron (ppm)	0.55	0.67
Clay (%)	21.5	19.2
Silt (%)	25.1	29
Sand (%)	53.4	51.8
Texture	Sandy clay loam	Loam

Mineral fertilizers: 1000 g N, 1500g K_2O and 400 g P_2O_5 per tree were applied to soil using calcium nitrate, potassium sulfate and mono-ammonium phosphate.

Furthermore, foliar boron fertilizer was obtained from (Valagro) and different concentrations were prepared for each dose (240 L, 60 L for each treatment except control) as the following: The initial prepared concentration was adjusted to 1600 ppm B by adding 1.59 L of foliar boron fertilizer (11 % v/v, 150.7g.L^{-1}) to 150 L water.

To obtain the lower concentration, the initial concentration was diluted according to general dilution equation :

Concentration(stat) x Volume(start) = Concentration(final) x Volume (final)

Foliar boron fertilizer was applied at five different concentrations (0, 400, 800, 1200 and 1600 ppm) to date palm trees in three equal doses at kimri stage (Fig. 2). Each tree was sprayed with 20L of specific concentration at 20th of May (6 weeks after pollination), 20th of June, and 20th of July. Both leaves and bunches were sprayed with spraying machines.

Soil analysis: Soil samples were collected in April. Six sub-samples of two depths (0-30 and 30-60 cm) were taken from the experimental field in zigzag pattern for obtaining one composite sample from each depth for further analysis. Soil texture, pH, EC,

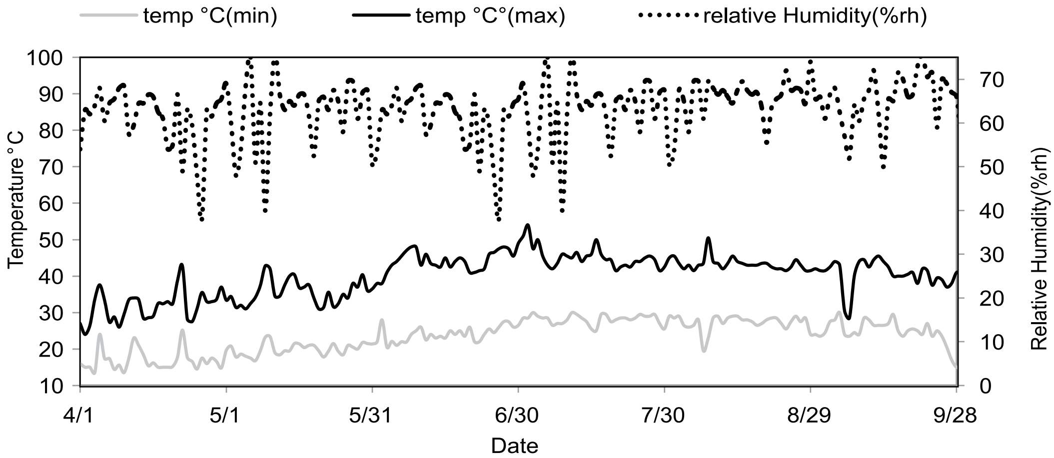

Fig. 1. Minimum (min) and maximum (max) recorded temperatures (°C) and relative humidity (%) in the experiment field at the University of Jordan Research Station, Jordan Valley Jordan, during 2017 reproductive seasons.

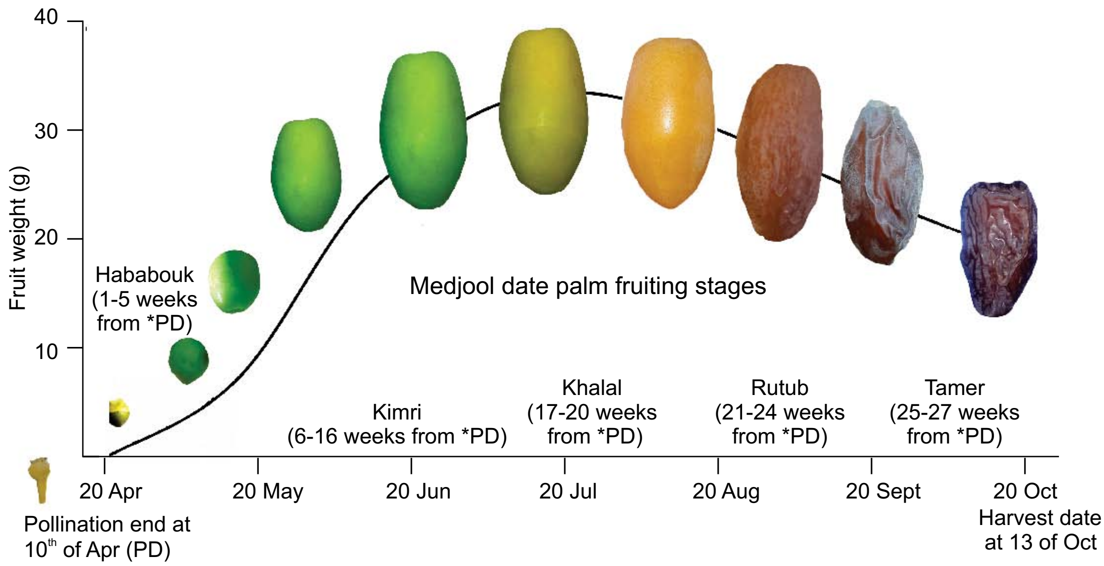

Fig. 2. Different Medjool date palm fruiting stages from pollination date (PD) at 10 of April 2017 until harvest date (13 of October, 2017) at University of Jordan Research Station. Jordan Valley.

organic matter and nutrient content were analyzed according to Estefan *et al*. (2013) methods of soil, plant, and water analysis.

Fruit thinning: At pollination date, the heart of each bunch was removed after that in mid of hababouk stage (Fig. 2) the strand and fruit thinning done manually to leave only 10 fruit in each strand and 35 strand in each bunch and in last step only 10 healthy bunch left in each tree with total number of fruit equal 3500 fruit per tree.

Fruit yield and fruit physical properties: Fruits were harvested at the 13th of October and average fruit yield (kg · tree^{-1}) and bunch weight were recorded. Fruit samples were randomly selected at mature tamer stage for fruit physical properties and fruit quality assessment. Twenty fruits were randomly selected from each tree to determine fruit weight (g), seed weight and flesh weight after seed removal for calculation of flesh weight ratio. Flesh weight ratio was calculated as:

$$\text{Flesh weight ratio} = \frac{\text{Flesh weight}}{\text{Fresh fruit weight}} \times 100$$

Fruit moisture content (%) was determined by drying fruit flesh at 70 °C for 96 hrs. until reaching weight stability. It was calculated according to the following equations:

$$\text{Fruit moisture content (\%)} = \frac{\text{Fresh fruit wt - Fruit dry wt}}{\text{Fresh fruit wt}} \times 100$$

Fruit size was measured based on fruit length (mm) using digital caliper. Fruit volume was, also, measured by water displacement method assuming 1 mL of water equal 1 cm^3 and fruit density calculated according to the following equation:

$$\text{Fruit density} = \frac{\text{Fresh fruit weight}}{\text{Fruit volume}}$$

Fruit retention percentage: the following equation was used to calculate of fruit retention percentage:

$$\text{Fruit retention \%} = \frac{\text{Actual yield}}{\text{Expected yield}} \times 100$$

Where,

Actual yield presented the achieved yield at harvest date, while expected yield calculated as:

Expected yield = Fruit fresh weight x Initial number of fruit left on each tree

Skin separation: Randomly selected fruit samples from each tree were visually sorted according to the incidence of fruit skin separation disorder. Percentage fruits skin separation was calculated by counting the number of fruits with skin separation to the total number of fruits.

Total soluble solid: The total soluble solid (TSS) was measured as Brix % in fruit juice according to Alsaed *et al*. (2015). Homogenous solution was prepared by blending 10 g of fruits flesh with 10 mL of distilled water, then the mixture was transferred to piece of gauze and squeezed to remove first droplets then Brix % was measured using a krus™ HR Series Manual Handheld Refractometers, Germany.

Fruit firmness: Five randomly selected fruits per tree were used to measure fruit firmness using CNYST GY-3 Fruit Hardness Tester penetrometer (CNYST, China).

Radical scavenging activity of DPPH: Date fruits antioxidant activity were determined using the 1-diphenyl-2-picrylhydrazyl (DPPH) free radical solution according to Brand-Williams *et al*. (1995) with some modifications: 10 g of date palm fresh fruit (tamer) were blended with 100 mL of absolute methanol and digested until reaching to homogenous mixture then filtered using No 1 whatmman filter paper. Stock solution of DPPH radical was prepared in 100 mL absolute methanol to make 0.004 % (w/v) solution. After making the desired concentrations 4ml of DPPH solution was applied to 1 mL of fruit sample extract (1 mL of absolute methanol in control) and vortex for 30 second, then absorbance of the mixed solution was measured at 517 nm using Beckman model DU-40 spectrophotometer. The DPPH scavenging activity was calculated using the following equation:

Fruit scavenging activity = ((Absorbance of control-Absorbance of sample)/ Absorbance of control) x 100

Sugar extraction and analysis: The sugar composition of the date palm fruit (tamer) was determined as mentioned by Langemeier and Rogers (1995), with some modifications. Five grams of fresh date fruit were placed in 150 mL volumetric flask and blended with 100 mL 70 % ethanol. The fruit sample was homogenized then filtered using (Whatmman filter no. 1). After that, samples were filtrated using 0.45 µm nylon type membrane filter syringe. Then the samples were ready for HPLC analysis.

HPLC analysis was done using Nexera LC20AD xr liquid chromatograph with RID 10A refractive index detector (Shimadzu, Japanese and (NH_2- R-P-Macherey-Angel-Germany 250 mm x 4.6 mm column). The eluent was 75:25 isocratic acetonitrile: water at flow rate of 1 mL/min and 30 °C. The calibration curve was created using 4 different levels (5, 7.5, 10 and 15 µg. mL^{-1}) of HPLC grade glucose, fructose and sucrose standard (Sigma-Aldrich, Germany).

Date syrup pH: For date syrup pH measurement, 100 g of fresh date fruit was placed in 1 L elementary flask and the volume adjusted to 500 mL using distilled water. Then samples were mixed using a hand-held blender. Elementary flask were placed for 2 hours in water bath at 70 °C after which samples were filtered through a cheese cloth to remove large impurities and insoluble matters, then sample pH was recorded.

Statistical analysis: All data were analyzed for treatments effects on measured parameters using SAS software (version 9 for Windows; SAS Institute, Cary, NC). A completely randomized design with five boron levels and three replicate was used. Means of different treatments were separated using Duncan's Multiple Range Test at P<0.05.

Results and discussion

Yield and fruit physical properties: Foliar application of B at high rate (1600 ppm) resulted in a significant increment in yield and bunch weight compared to control (Table 2). The foliar application of boron at1600 ppm increased fruits yield and bunch weight by 27 % and 25 % over control (67.7 vs. 53.4 kg·$tree^{-1}$) and (6.8 vs. 5.4 kg·$bunch^{-1}$), respectively. The foliar application of B enhanced fruit retentions (88 % at 1600 ppm vs. 81 % in control) (Fig. 3). These results were found in agreement with the Omar *et al*. (2014) and Shareef (2016). These increment in fruit retention due to boron may be attributed to its role in cell wall metabolism in higher plants (Blevins and Lukaszewski, 1998), growth and development of fruit (Goldbach, 1997; Marschner, 1995), formation of borate cross-links of pectin in presence of Ca^+ to produce more cemented cell wall (Blevins and Lukaszewski, 1998), especially in abscission zone during fruit development which result in improving fruiting rate (Tsukahara *et al*., 2013). Foliar boron treatment also increased average fruit fresh weight, dry weight and flesh weight, especially at 1600 ppm which caused 16 % increased of fruit weight, dry weight and flesh weight over control (22.0 vs. 18.9 g.$fruit^{-1}$), (16.9 vs. 14.6 g.$fruit^{-1}$) and (20.9 vs. 18.0 g.$fruit^{-1}$), respectively (Table 2). Same findings reported by Khayyat *et al.* (2007) and Elsabagh (2012) which could be as a result of boron contribution to proper development and differentiation of fruit tissues (Goldbach, 1997; Marschner, 1995), up regulation of photosynthesis (Han *et al.,* 2008), translocation of sugar from leaf to fruit (Gauch and Dugger, 1953). In this regard, increase in yield due to boron foliar application was attributed mainly to its effect on increasing fruit retention (Davarpanah *et al*., 2016) (Fig. 3A), in addition, due to boron foliar application effect on increasing fruit weight (Fig. 3B).

The results also showed significant differences among different B foliar applications rates on fruit size and fruit volume (Table 4). 1600 ppm B contributed to the maximum fruit size (49.97 vs.

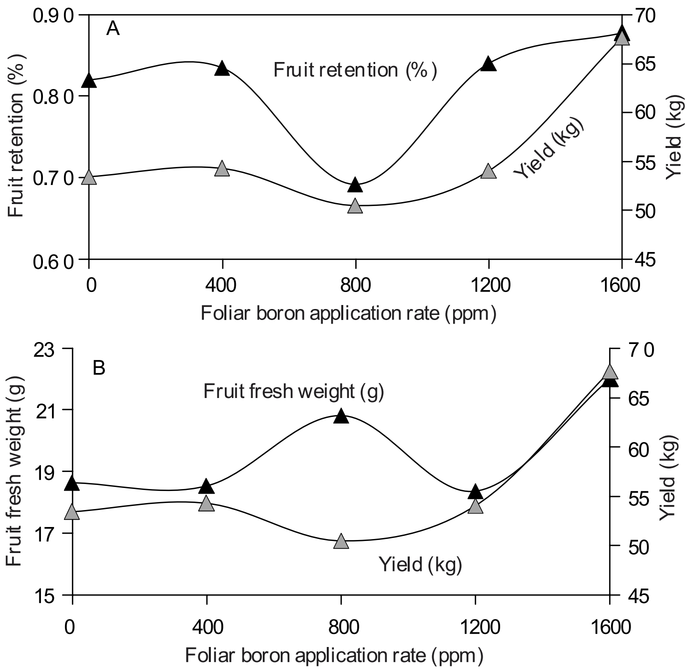

Fig. 3. The effect of foliar boron fertilizer rate on Medjool date palm yield, fruit fresh weight and fruit retention (A) the correlation between fruit retention (▲)and yield (▲), (B) the correlation between fresh fruit weight (▲) and yield (▲).

Table 2. Effect of different boron foliar application rate on yield and physical properties of Medjool date palm *P. dactylifera* L. fruits at tamer stage

Boron rate (ppm)	Yield (kg· $tree^{-1}$)	Bunch weight kg· $bunch^{-1}$	Fruit fresh weight (g·$fruit^{-1}$)	Fruit flesh weight (g·$fruit^{-1}$)	Dry weight (g·$fruit^{-1}$)	Moisture (%)	Seed weight (g)	Flesh net weight (%)
400	54.3b	5.4b	18.52c	17.4 c	14.0c	19.2	1.16a	93.48c
800	50.5b	5.1b	20.81b	19.6b	15.9b	18.7	1.03c	94.25b
1200	54.0b	5.4b	18.36c	17.3c	14.0c	19.6	1.17a	94.27b
1600	67.7a	6.8a	22.00a	20.9a	16.9 a	19.6	1.11b	94.83a
Control	53.4b	5.4b	18.96c	18.0c	14.6c	18.8	0.94d	94.97a
F-test	*	*	***	***	***	NS	***	***
Error df	10	10	295	295	295	295	295	295
Error MS	30.26	0.31	9.58	9.6	6.4	0.0007	0.012	0.0001

Mean values within same column bearing different letters a, b, c, d are significantly different (P< 0.05) on application of Duncan's multiple range test (DMRT). *, **, ***significant at P > 0.05, 0.01 and 0.001, respectively, Error df= Error Degrees of Freedom, Error MS=Error Mean Square.

Table 3. Effects of different boron foliar applications rate on yield and fruit retention percentage of Medjool date palm *Phoenix dactylifera* L. fruits at tamer stage

Boron (ppm)	Actual yield kg· (tree^{-1})	Expected yield (kg· tree^{-1})	Fruit retention (%)
400	54.3b	65.05	0.837b
800	50.5b	72.93	0.693c
1200	54.0b	64.30	0.840b
1600	67.7a	77.07	0.877a
control	53.4b	65.20	0.817b
F-test	*		***

Mean values within same column bearing different letters a, b, c, d are significantly different (P< 0.05) on application of Duncan's multiple range test (DMRT).
*, **, ***significant at P > 0.05, 0.01 and 0.001, respectively, Error df= Error Degrees of Freedom, Error MS=Error Mean Square.

45.3 mm) which reflected on increased bunch weight and yield (Mostafa, 2015). Fruit volume significantly increased compared to control (17.3 vs. 14.7 cm^3), while fruit density and fruit skin separation incidence (grade) were not affected by different B applications. On the other hand, lower B levels (400 ppm) resulted in significant increment in seed weight (1.16 vs. 1.11g) and flesh net weight (93.48 % vs. 94.97) compared to control (Table 2). Pearson correlation coefficients showed high significant and positive correlation between B treatment, yield, fruit weight, flesh weight, seed weight, fruit dry weight, fruit size and fruit volume (Table 5).

Fruit skin separation was not affected by foliar B application. Mechanical properties of fruits at maturity time were supposed to be responsible for skin separation traits in Medjool (Lustig *et al.,* 2014) and Barhee fruits (Gophen, 2014). High temperature and high humidity (Fig. 1) before the beginning of ripening stages also supposed to play a major role in increasing skin separation defect in dates (Ait-Oubahou and Yahia, 1999). Nixon (1961) suggested the negative impact of excessive turgor in peripheral tissue at beginning of fruit ripening when associated with high temperatures and high humidity at earlier stages.

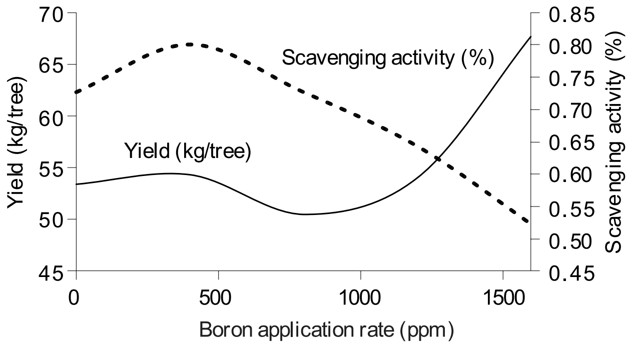

Fig. 4. Relationship between Medjool date palm yield at tamer stage and date palm fruits DPPH scavenging activity as response to different boron application rate.

Fruit quality: Result showed low but significant variation in TSS (Brix %) between different B applications where low B level (400 ppm) increased TSS compared to the control (75.0 % vs. 73.4 %) (Table 4). Nevertheless, higher application rates resulted in decreased TSS without any significant difference between them and control. (Sarrwy *et al.,* 2012) reported that spraying date palm inflorescence with both boric acid and/or calcium nitrate affected fruit chemical characteristics of Amhat date palm, which could

Table 4. Effects of different boron foliar applications on physical and chemical quality characters of Medjool date palm *Phoenix dactylifera* L. fruits at tamer stage

Boron rate (ppm)	Fruit size (mm)	Fruit volume (cm^3)	Fruit density (g.cm^{-3})	Skin separation (%)	Fruit firmness (kg.cm^{-2})	Total soluble solid %	DPPH scavenging activity (%)	Date syrup pH
400	44.17 c	14.4 b	1.21	36.7	5.56 a	75.0 a	80.0a	4.75
800	44.10 c	14.6 b	1.19	35.0	4.44 bc	73.9 ab	72.7b	4.76
1200	47.95 b	16.3 a	1.21	36.7	3.89 c	73.2 b	64.3c	4.68
1600	49.97 a	17.3 a	1.22	35.0	4.61 bc	73.2 b	52.3d	4.77
Control	45.30 c	14.7 b	1.23	33.3	5.00ab	73.4 b	72.7b	4.69
F-test	***	***	NS	NS	**	*	***	NS

Mean values within same column bearing different letters a, b, c, d are significantly different (P< 0.05) on application of Duncan's multiple range test (DMRT).
NS, not significant; *, **, ***significant at P > 0.05, 0.01 and 0.001, respectively, Error df= Error Degrees of Freedom, Error MS=Error Mean Square.

Table 5. Pearson correlation between different boron foliar application rate, Medjool date palm yield and some Medjool date palm fruits physical properties at tamer stage

	Boron level	Yield	Fruit weight	Seed weight	Fruit dry weight	Fruit size	Fruit volume
Boron level	1						
Yield	0.53*	1					
Fruit weight	0.71**	0.63*	1				
Seed weight	0.55*	0.17 ^{NS}	0.26 ^{NS}	1			
Fruit dry weight	0.69**	0.63*	0.99 ***	0.21 ^{NS}	1		
Fruit size	0.69 **	0.41 ^{NS}	0.81 ***	0.19 ^{NS}	0.81***	1	
Fruit volume	0.73 **	0.59*	0.98***	0.21 ^{NS}	0.98 ***	0.82***	1

NS, not significant; *, **, ***significant at P> 0.05, 0.01 and 0.001, respectively be a result of boron role in sugars transport by forming a sugar-borate complex which moves through cellular membranes more readily than non-borated (Gauch and Dugger, 1953).

Fruit firmness was also significantly affected by boron applications with maximum firmness value obtained at 400 ppm compared to control (5.56 vs. 5.00 kg.cm^{-2}), while increasing B rate resulted in a significant decrease in fruit firmness (Table 4). Similar responses were reported for decreased fruit firmness with response to high boron levels (3000 ppm) in mango (Ali *et al.,* 2017) and after bloom sprays in apple (Wojcik *et al.,* 1999). Such responses could be explained by the role of boron in water transportation to aerial plant parts and its role in controlling leaf water loss (Wimmer and Ei-chert, 2013; Wang *et al.,* 2015) which may lead to maintain good water status at high rate of foliar B application and decrease dehydration rates.

Antioxidants activities in fruits were also influenced by boron treatments (Table 4). DPPH scavenging activity at low rate foliar boron application (400 ppm) was significantly higher than scavenging activity in control fruits (80 vs. 72.7 %). Similar finding was reported by Ruiz *et al*. (1998) in tobacco leaves. Additionally, negative correlation between B level and DPPH scavenging activity was observed (Table 6) where antioxidant activities started declining at B levels above 800 ppm. DPPH activity was negatively correlated with fruits yield (Fig. 4). The highest fruits yield, obtained at 1600 ppm, was associated with minimum scavenging activity (52.3 %). This finding suggest that high rate of foliar boron application resulted in considerable effect on net photosynthesis rate and decreased oxidative damage by toxic O_2 species resulted by less efficient photosystem (Brown *et al.,* 2002). Han *et al.* (2008) reported decrease in scavenging capacity of citrus seedlings in response to boron application levels which reflects boron role in phenolic metabolism, in addition to its role in enhancing plant water status (Shehzad *et al.,* 2016).

Table 6. Pearson Correlation between different boron foliar application rate, Medjool date palm yield and some Medjool date palm fruits physical and chemical properties at tamer stage

	Boron level	Yield	DSA	Skin separation	Fruit firmness
Yield	0.53*	1			
DSA	-0.81***	-0.63*	1		
Skin separation	0.09^{NS}	0.13^{NS}	0.15^{NS}	1	
Fruit firmness	-0.66**	-0.10^{NS}	0.34 ^{NS}	-0.21^{NS}	1
TSS brix	-0.60*	-0.32^{NS}	0.35^{NS}	-0.04^{NS}	0.74**

NS, not significant; *, **, ***significant at P>0.05, 0.01 and 0.001, respectively. DSA=DPPH scavenging activity

Table 7. Duncan's multiple range test (DMRT) of the effects of different boron foliar applications rate on sugar content of Medjool date fruits at tamer stage

Boron rate (ppm)	Glucose (g·100g^{-1})	Fructose (g·100g^{-1})	Total reducing sugar (g·100g^{-1})	Glucose/ fructose ratio
400	43.17a	39.28a	82.45a	1.099a
800	40.13b	37.05a	77.18ab	1.083ab
1200	33.51c	31.29b	64.81c	1.071b
1600	39.05b	36.55a	75.59b	1.068b
Control	30.41d	28.69b	59.10d	1.059b
F-test	***	***	***	*
Error df	10	10	10	10
Error MS	2.51	2.23	9.26	0.0002

* Means value within same column bearing different letters a, b, c, d are significantly different (P< 0.05) on application of Duncan's multiple range test (DMRT).

B= boron, NS, not significant; *, **, ***significant at P < 0.05, 0.01 and 0.001, respectively, Error df= Error Degrees of Freedom, Error MS=Error Mean Square.

Fruit sugar content: The result showed that fructose and glucose were the only sugars found in the date flesh samples (Table 7). Sucrose content was negligible and no clear peak was found in HPLC chromatogram compared to standard chromatogram which resulted by hydrolysis of sucrose during ripening of date fruit (Chao and Krueger, 2007). Sugar content was significantly affected by B application where 400 ppm resulted in higher reduced sugars; fructose content (39.28 vs. 28.69 %), glucose content (43.17 vs. 30.41 %) and glucose to fructose ratio (1.1 vs. 1.059) as compared to control (Table 7), The presence of only reducing sugars suggests the existence of marked invertase activity, which considerably reduces sucrose content and hydrolyses to glucose and fructose (Rastegar *et al.,* 2012). On the other hand boron fertilizer enhanced carbohydrate metabolism (Goldbach, 1997) which resulted in significant difference in total reduced sugars (82.45 % vs. 59.1 %) between 400 ppm B treatment and control, in addition to facilitate sugars transport from source to sink (Gauch and Dugger, 1953) which is one of the most important factors affecting production yield and quality of fruit (Fischer *et al.,* 2012) and maintain high photosynthetic capacity and decrease the negative feedback inhibition of accumulation of assimilates in leaf (Goldschmidt and Huber, 1992)

The results obtained from this study recommend the use of 1600 ppm of boron on Medjool date palm to improve yield, fruit weight, and flesh weight and fruit size with no effect on fruit skin separation. On the other hand, lower rates (400 ppm) were recommended in enhancing fruit quality in Medjool fruits.

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