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Evaluation of Amino Chelate Applications that Reduce Symptoms of Date Palm Bunch Fading Disorder

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ABSTRACT

Bunch fading disorder in date palm is a serious problem in date fruit production around the world. During their growth and development, bunches of date fruit were treated with amino chelates of Mn (2 or 4 ppm), Cu (2 or 4 ppm), Zn (2 or 4 ppm), Ca (4 or 6 ppm), K (5 or 7 ppm). The effects were evaluated on bunch fading disorder, as well as on qualitative features and quantitative traits of date palm fruit (*Phoenix dactylifera* L.). This research was conducted on 15-year-old date palm trees (cv. 'Mazafati') in a randomized complete block design with 11 treatments in three replications. Fruit bunches were sprayed with amino chelates twice during fruit development, i.e. in the Hababook and Khalal stages. The results showed that all amino chelates reduced the percentage of damage caused by the fading disorder. The highest percentage of damage (36.67%) was recorded in the control group because it had received no spraying treatment. In treatment groups, however, the amino chelates had significant effects on fruit yield, seed weight, seed length, pH, TSS, and fruit moisture. The lowest amount of fruit yield was observed in the control group (44.5 kg), whereas all treatment groups staged a significant increase in yield. Specifically, high amounts of fruit yield were caused by Mn-2ppm (65.83 kg), Cu-2ppm (64.33 kg), Ca-4ppm (62.17 kg) and Cu-4ppm (60.83 kg). All treatments increased the fruit moisture content, compared to the control, and had significant effects on some chemical traits of date leaves and fruits. A significant increase in pigments occurred as a result of amino chelate spraying. In sum, amino chelates were significantly effective in reducing the bunch fading disorder.

Introduction

Bunch fading disorder in date palm is usually recognized as a problematic issue in date fruit production. In particular, the 'Mazafati' cultivar is highly susceptible to this disorder (Panahi et al., 2013). The bunch fading disorder usually appears from the stage of Khalal to Rutab. As the fruits wither, the tip of the spikelet axis dries. Brown spots appear and then the whole spikelet axis dries along with the fruits. In some cultivars, such as 'Mazafati', in some cases, a brown strip appears on the tail of the main bunch, which finally results in bunch tail drying and lignifications (Panahi et al., 2013). There have been several hypotheses about the causes of this disorder, the most important of which are climatic factors (Mohammadi and Moghtaderi, 2005; Izadi and Shahsavar, 2015), pathogens, fungal agents in particular (Alavi, 2004; Najafinia and Alavi, 2004), nutrient deficiencies and a lack of management in orchards (Pezhman, 2004). A substantial amount of research has been carried out on the said hypotheses since 2000. Mohammadi and Moghtaderi (2005) reported that a decrease in relative humidity and an

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increase in temperature were among the main causes of date bunch fading, especially when date trees are subjected to severe, sudden environmental stress (Panahi, 1999). Previous studies by Izadi and Asl-Moshtaghi (2014) showed that harsh climatic factors accelerated the occurrence of the disorder, whereas proper orchard management led to a significant decrease in the disorder. It was observed that applying integrated practices was more effective than using each practice per se. In fact, effective results were reportedly achieved in combining several management practices such as plowing, leaf pruning, proper nutrition, regular irrigation, pollination, regulation of leaf bunch ratio, thinning in the pollination stage, as well as the control of weeds, pests, and diseases. The foliar application of trace elements such as zinc, boron and calcium played an important role in fruit formation, while assisting in fruit growth and development, thereby generating adequate amounts of yield and enhanced fruit quality (AlHejjaj and Ayad, 2018; Omar et al., 2015). Since calcium is needed for cell division and cell elongation, it is considered as one of the most important elements in shaping fruit quality (Hocking et al., 2016). Zinc is used for increasing the number, size, and quality of fruits. Furthermore, zinc can be effective in improving the performance of quality parameters and in reducing fruit loss (Swietlik, 2002). Copper usually plays an important role in plant growth, vitamin A formation, flowering, fruit formation, fruit color, and fruit quality (López-Vargas et al., 2018; Hippler et al., 2018). Potassium is an essential mineral element that is involved in many physiological processes, including growth, yield, quality, enzymatic activity, maintenance of tourniquets, and stress tolerance (Wang et al., 2013). Meanwhile, using manganese via soil application is difficult because of its particular rate of efficiency which depends on many factors, including soil pH. A suitable method for alleviating manganese deficiency in plants is the foliar spraying of the element in its ionic form or as chelates (Souri, 2016). Amino chelate fertilizers are the latest novelties in plant nutrition and agricultural applications. They are among new, modern formulae of fertilizers which are synthesized based on various amino acids. The application of amino chelates, as a replacement for routine fertilizers, can potentially result in higher nutrient uptake and fewer negative side effects (Souri, 2016). Chelators or chelating agents are chemical compounds that have a high affinity to bond tightly with a metal ion, thereby forcing the metal atoms to follow the chelating molecule. The chelating effect is mainly due to several bonds by which a ligand molecule can enclave a single metal ion. In other words, a chelating agent is a multidentate ligand that forms at least two and up to eight bonds with a single metal ion, so that protection is provided against unwanted reactions in the soil and inside the plant (Souri, 2015). While many farmers are becoming familiar to amino chelate fertilizers in recent years, markets in some countries are increasingly making amino chelates a popular form of fertilizer (Souri, 2016; Panahi et al., 2020). Amino chelates can contribute to protein formation as a prerequisite to the synthesis of plant hormones, while assisting in the synthesis of essential metabolites such as chlorophyll, glycine and glutamic acid. Amino chelates can be effective in buffering the environment for a better absorption of soil-borne microelements, while increasing chlorophyll content and contributing to the bioavailability of amino acids such as methionine, spermidine, and tryptophan for an adequate biosynthesis of plant hormones (Kalaji et al., 2018; Nasseri et al., 2013). Given the information in the available literature, there seems to be a gap in knowledge about the effectiveness of amino chelates in certain untested contexts. Thus, the objective of this study was to evaluate how amino chelates, through spraying, can alleviate the severity of bunch fading disorder and control the decline in date palm yield (*Phoenix dactylifera* L. cv. 'Mazafati').

Materials and Methods

Experimental location

The present study was carried out on 15-year-old date palm trees (*Phoenix dactylifera* L. cv. 'Mazafati') at the Azizabad Agricultural Research Station. The orchard was 741 m above sea level, with a longitude of 58• 5' 6.768'' and a latitude of 28• 56' 7.041''.

Experimental design and treatments

A randomized complete block design (RCBD) was laid out in three replications, whereby 33 trees were treated with 10 foliar spraying doses and a control group as follows:

Mn-2: Manganese amino chelate (2 ppm)
Cu-2: Copper amino chelate (2 ppm)
Zn-2: Zinc amino chelate (2 ppm)
Ca-4: Calcium amino chelate (4 ppm)
K-5: Potassium amino chelate (5 ppm)
Mn-4: Manganese amino chelate (4 ppm)
Cu-4: Copper amino chelate (4 ppm)
Zn-4: Zinc amino chelate (4 ppm)
Ca-6: Calcium amino chelate (6 ppm)
K-7: Potassium amino chelate (7 ppm)
C: Control with no foliar spraying

Application of experimental treatments

Foliar spraying of the amino chelates was applied twice, during the growth and development of date fruits. The first time of application was at the Hababook stage and the second was at the Khalal stage. The date orchard, where foliar spraying was performed and samples were collected, had a previous contamination background of date bunch fading disorder. The experiment was carried out from 2016 to 2017.

Measuring traits

Fifty fruits were randomly harvested from four clusters on each tree. The clusters were selected from four different directions on each tree, and the percentage of dried fruits was calculated as the damage caused by the bunch fading disorder. Measurements were aimed at quantitative and qualitative traits, such as fruit length, diameter and weight, as well as seed weight, pH, moisture, and yield, according to A.O.A.C instruction (1980). Total soluble solids (TSS) in fruit juice were measured as Brix° (Alhejjaj and Ayad, 2018). A homogenous solution was prepared by squashing fruit flesh (10 g) and blending it with distilled water (10 ml). The mixture was transferred to a piece of gauze and squeezed to remove the first droplets. Then, the TSS (Brix°) was measured using a handheld refractometer (Krus™ HR Series, Germany). Date leaves and fruits were oven-dried at 70º C until a constant weight was reached, and then the dried material was ground to a powdery texture. Accordingly, 0.2 g of the powder was sampled to determine the amounts of different elements. Potassium was estimated by flame-photometry. Copper, manganese and zinc were determined by atomic absorption spectrophotometry. Fe, calcium and magnesium were determined by a titration method (Emami, 1997; Álvarez- Fernández et al., 2003; El-Razek et al., 2011). The chlorophyll contents of the leaves and fruits were determined by spectrophotometric analysis of chemically extracted pigments. For this purpose, a total of 270 samples were collected. The samples were collected, immediately wrapped in aluminum foil and stored in ice. They were transferred to the laboratory and stored at −80 °C until further analysis was appropriate, according to methods by Arnon (1949) and Wellburn (1994). Briefly, the samples were ground in liquid nitrogen and extracted in 80% ethanol at room temperature after centrifugation. Pigment absorption was measured spectrophotometrically at 663, 645, and 470 nm, and converted parametrically into pigment contents using the following equations:

$$Chlt\ (\mu g \cdot cm^{-2}) = [(20.2 \times A645) + (8.02 \times A663)] \times mL\ of\ Acetone80\%/Leaf\ Area\ (cm^2)$$

$$Chla\ (\mu g \cdot cm^{-2}) = [(12.7 \times A663) - (2.6 \times A645)] \times mL\ of\ Acetone80\%/Leaf\ Area\ (cm^2)$$

$$Chlb\ (\mu g \cdot cm^{-2}) = [(22.9 \times A645) - (4.68 \times A663)] \times mL\ of\ Acetone80\%/Leaf\ Area\ (cm^2)$$

Climate data

Average air temperature, relative humidity, wind speed, and monthly evaporation were considered contextually from May to August (2016-2017) (Fig. 1).

Statistical analysis

The data on various parameters were collected and analyzed statistically using MSTAT statistical package. Variations in data were observed in response to the experimental treatments. After two years, the combined ANOVA was performed and their mean values were compared by Duncan's test (α=5%).

Results

The effects of amino chelate treatments on bunch fading disorder

Statistical analysis showed that all levels of amino chelates were significantly effective in alleviating bunch fading disorder ($p < 0.01$). Spraying amino chelates on the bunches reduced the percentage of damage caused by the bunch fading disorder. The highest percentage of damage (36.67%) was recorded in the control group and the lowest percentage (5%) occurred in response to manganese amino chelate (2 ppm) (Table 1).

Impact of amino chelates on quantitative and qualitative traits of fruits

The results showed that amino chelates had significant effects on seed weight, seed length, fruit yield, pH, TSS, and fruit moisture (Table 1). The application of treatments had no significant effect on fruit weight, fruit flesh weight, fruit length, fruit diameter, and seed diameter. The lowest amount of fruit yield was observed in the control group (14.5 kg), whereas all treatments caused significant increases in fruit yield. Specifically, high amounts of fruit yield occurred in response to Mn-2, Cu-2, Ca-4, and Cu-4, which caused 65.83, 64.33, 62.17, and 60.83 kg fruits/tree, respectively. Amino chelates had no significant effect on TSS, however, and there was no significant difference between the effects of amino chelates and the control group in this regard (Table 2).

Nonetheless, the highest TSS was found in the control treatment (58.33).

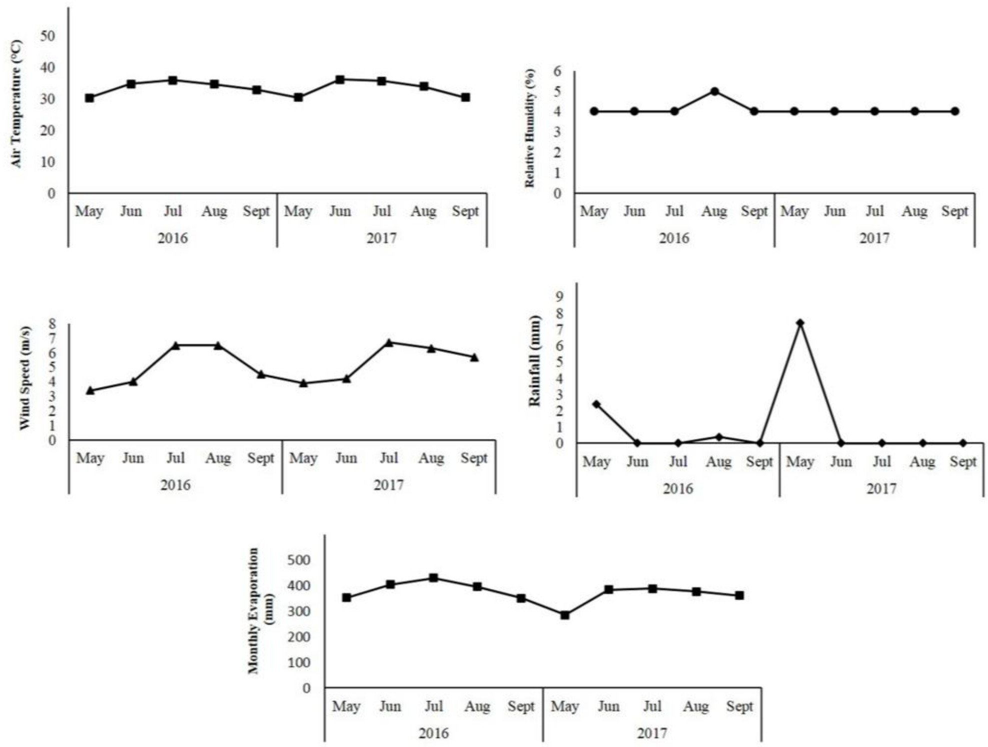

Fig. 1. Average air temperature, relative humidity, wind speed, and monthly evaporation from April to August (2016–2017) at the Azizabad Agricultural Research Station, Narmashir, near Bam area, Kerman, Iran.

Table 1. Comparison of mean values pertaining to different levels of treatments on the quantitative and qualitative traits of date fruits

Mean comparisons												
Treatment	Damage (%)	Fruit Weight (mg)	Seed weight (mg)	Fruit flesh Weight (mg)	Fruit length(cm)	Seed length (cm)	Fruit diameter (cm)	Seed diameter (cm)	Yield (kg)	pH	TSS	Fruit Moisture (%)
Mn-2	5.0c	183.5b	13.2c	170.2b	54.7a	30.8a	35.4ab	12.28a	65.83a	6.8a	53.6a	33.8a
Cu-2	6.16c	220.4ab	16.8a	209.9ab	56.0a	32.1ab	37.4ab	12.73a	64.33a	6.83a	55.0a	33.2a
Zn-2	5.5c	219.7ab	15.2abc	210.3ab	57.9a	32.5a	38.0a	12.82a	55.83ab	6.66ab	55.7a	32.5a
Ca-4	5.5c	202.5ab	14.7abc	186.8ab	54.9a	30.8ab	35.8ab	12.75a	62.17a	6.63ab	55.6a	33.1a
K-5	8.66c	214.6ab	14.2bc	200.3ab	58.4a	33.1a	36.9ab	12.32a	59.17ab	6.86a	54.5a	30.5ab
Mn-4	5.66c	228.2a	15.8ab	211.7a	57.5a	31.7ab	36.0ab	12.28a	58.33ab	6.71ab	37.4b	33.4a
Cu-4	6.5c	191.5ab	13.7bc	177.3ab	56.0a	30.1b	34.7b	12.18a	60.83a	6.81a	53.3a	31.8ab
Zn-4	15.5bc	199.7ab	14.2bc	185.2ab	54.9a	30.9ab	36.4ab	12.63a	57.83ab	6.85a	54.6a	32.6a
Ca-6	5.5c	205.0ab	14.6abc	190.4ab	55.4a	30.0b	36.8ab	12.32a	57.5ab	6.67ab	53.5a	32.0a
K-7	20.0b	206.2ab	15.8ab	190.5ab	56.2a	31.3ab	36.5ab	12.57a	49.17bc	6.63ab	47.3ab	29.7ab
C	36.67a	214.9ab	14.5abc	200.3ab	57.3a	32.6a	34.9ab	12.45a	44.5c	6.50b	58.3a	27.9b

Mean values in each column with the same letter are not significantly different at the 5% level based on Duncan's test, whereas values with different letters are significant.

Mn-2: Manganese amino chelate (2 ppm); Cu-2: Copper amino chelate (2 ppm); Zn-2: Zinc amino chelate (2 ppm); Ca-4: Calcium amino chelate; (4 ppm); K-5: Potassium amino chelate (5 ppm); Mn-4: Manganese amino chelate (4 ppm); Cu-4: Copper amino chelate (4 ppm); Zn-4: Zinc amino chelate (4 ppm); Ca-6: Calcium amino chelate (6 ppm); K-7: Potassium amino chelate (7 ppm); C: Control with no foliar spraying.

The highest percentage of fruit moisture (33.87%) occurred in response to the Mn-2 treatment. The application of all treatments increased the fruit moisture content, compared to the control group (Table 1). The Mn-4 treatment improved the fruit weight (228.2 mg) and fruit flesh weight (211.7 mg). The K-5 treatment increased the fruit length (58.4 cm), seed length (33.13 cm) and pH (6.868) more than the other treatments did. The largest fruit diameter (38.07 cm) and seed diameter (12.82 cm) occurred as a result of the Zn-2 treatment.

Effect of the amino chelate treatments on chemical traits of date leaves and fruits

The results showed that the application of amino chelate treatments had significant effects on the levels of potassium, calcium, manganese and magnesium in date palm leaves, as caused by Ca-4, K-7, K-5, and K-7, respectively (Table 2). The analysis of chemical traits in date fruits showed that amino chelates had significant effects on all elements [potassium (Cu-4), calcium (Zn-2), manganese (K-5), magnesium (K-5), iron (Mn-2), and boron (Mn-4)] (Table 2). The foliar application of manganese at levels higher than Mn-4 reduced iron uptake in the leaves (from 0.34 to 0.15) and in the fruits (from 68.33 to 23.67). The highest mean value of Fe concentration in the fruits (68.33) occurred in response to Mn-2. This treatment caused a significant increase in the amount of iron uptake by the fruits, compared to the control and all other treatments (Table 2). The manganese amino chelate increased Mn (12.50) and Mg (12.50) absorption in fruits, compared to the control (8.16). Table 2 shows that Cu-4 increased manganese uptake in the leaves (from 26.48 to 29.12). The Cu-4 treatment reduced iron uptake in the leaves (from 0.53 to 0.22) and in the fruits (from 29.33 to 23.83). Higher levels of copper (Cu-4) increased potassium uptake in fruits (from 0.82 to 0.95), compared to the control (0.91). Potassium amino chelate increased iron absorption in the leaves and fruits, compared to the control treatment. Higher potassium levels increased iron uptake in the leaves (from 0.91 to 0.99) but reduced iron uptake in the fruits. The K-5 treatment significantly increased the amount of manganese in fruits (26.33), compared to the control and all other treatments (Table 2). The highest calcium content in fruits (7.7) occurred in response to the Zn-2 treatment. As the level of zinc increased, calcium absorption decreased in fruits (4.9), although it was still higher than in the control group (2.8). Antagonistic relationships were observed between zinc and manganese. Increasing the zinc level beyond Zn-2 caused a decrease in manganese uptake in the leaves and fruits (Table 2). The results in Table 2 show that Ca-6 increased boron uptake in the leaves (from 17.83 to 21.9) and in the fruits (from 6.16 to 13.17). It also increased calcium content in the fruits (3.4). Through foliar application, Ca-6 significantly increased the absorption of magnesium in the fruits (15.33), compared to the control group (8.16).

Impact of amino chelate treatments on pigment content

The pigment content of leaves and fruits were affected by amino chelates (Table 3). As can be seen, the results indicated a significant increase in the content of all pigments as a result of spraying amino chelates. The highest chl a content (2.232) occurred in response to the Cu-2 treatment. The highest levels of chl b (1.286) and chl t (3.433) in fruits were recorded in response to the K-7 treatment, and the highest chl b content (5.01) was observed by the Zn-4 treatment. Moreover, the highest levels of chl a (14.36) and chl t (18.41) in the leaves resulted from calcium amino chelate at 4 ppm (Table 3).

Discussion

Most soils are generally poor in organic matter, and improving their condition can play an important role in soil fertility. While nutrient elements are obviously necessary for plant growth and fruit production (Rousta, 2004), the results showed that applying the amino chelates of different elements and concentrations led to a variety of results. The amino chelates of manganese, copper, zinc, calcium and potassium reduced the bunch fading disorder to 5%, 6.1%, 5.5%, 5.5% and 8.7%, respectively, compared to the control group (36.67%). It seems that optimal nutrition for date trees has an important role in reducing the damage caused by the disorder (Izadi and Asl-Moshtaghi, 2014; Mohebbi, 2010). While destructive effects can be brought about by free radicals, substances that act as antioxidants can reduce the harmful effects. Previous research indicated that the antioxidant properties of amino chelates can increase fruit quality and peel firmness (López-Vargas et al., 2018; Souri, 2016). Using macro- and micro-nutrients in the form of amino chelates can increase the activity of antioxidant pathways which, in turn, can increase the antioxidant capacity of plants under stress (Yaish, 2015). The results showed that foliar-spraying the trees with experimental treatments of amino-chelates caused higher fruit yield, compared to the control group (Abotalebi Jahromi and Naseri, 2015; Naseri et al., 2013). Enhanced levels of plant growth and performance, as well as higher yield and quality, are achievable through amino chelate fertilizers which are comparable to routine chemical fertilizers such as sulfate salts (Ghasemi et al., 2013).

Rousta (2004) reported that foliar-spraying potassium sulfate and calcium chloride alone or in combination with fertilizers, containing trace elements, controlled the percentage of dried bunches and fruits significantly, while increasing the fruit yield.

Table 2. Mean comparison of different levels of the treatments on the chemical traits of date leaves and fruits during the biennium.

Treatments	leaves of date palm						Fruits of date palm					
	Mean Squares (MS)						Mean Squares (MS)					
	K	Ca	Mn	Mg	Fe	B	K	Ca	Mn	Mg	Fe	B
Mn-2	1.02b	0.40b	17.05d	0.34b	0.34b	24.25ab	0.59d	3.93f	12.33c	12.33c	68.33a	7.83b
Cu-2	0.97c	0.32d	26.48c	0.53b	0.53b	26.92ab	0.82ab	5.28d	21.67ab	21.67ab	29.33d	7.00c
Zn-2	1.34ab	0.44b	34.72b	0.42b	0.42b	19.68ab	0.72c	7.7a	13.17c	13.17c	38.5c	7.5c
Ca-4	1.89a	0.25e	42.6b	0.55b	0.55b	17.83b	0.84ab	2.83h	11.17d	11.17d	29.5d	6.16c
K-5	1.18b	0.54ab	55.83a	0.91a	0.91a	16.67c	0.60d	5.45c	26.33a	26.33a	54.83b	7.83b
Mn-4	1.03b	0.49ab	32.47b	0.15d	0.15d	17.58b	0.81ab	2.6i	12.50c	12.50c	23.67e	13.83a
Cu-4	0.91d	0.30d	29.12b	0.22c	0.22c	27.92a	0.95a	5.44c	17.67b	17.67b	23.83e	10.17b
Zn-4	1.56ab	0.35c	26.17C	0.53b	0.53b	22.42ab	0.86ab	4.95e	8.067e	8.06e	37.67c	8.00bc
Ca-6	1.61ab	0.33d	30.18b	0.50b	0.50b	21.92ab	0.90ab	3.45g	15.33c	15.33c	40.65c	13.17a
K-7	1.19b	0.61a	32.33b	0.99a	0.99a	18.5b	0.76b	5.93b	11.67d	11.67d	41.5c	8.00b
C	1.5ab	0.4433b	27.17c	0.4233b	0.4233b	19.67ab	0.9133ab	2.88h	8.16e	8.16e	33.00c	13.67a

Mean values in each column with the same letter are not significantly different at the 5% level based on Duncan's test, whereas values with different letters are significant.
Mn-2: Manganese amino chelate (2 ppm); Cu-2: Copper amino chelate (2 ppm); Zn-2: Zinc amino chelate (2 ppm); Ca-4: Calcium amino chelate; (4 ppm); K-5: Potassium amino chelate (5 ppm); Mn-4: Manganese amino chelate (4 ppm); Cu-4: Copper amino chelate (4 ppm); Zn-4: Zinc amino chelate (4 ppm); Ca-6: Calcium amino chelate (6 ppm); K-7: Potassium amino chelate (7 ppm); C: Control with no foliar spraying.

Table 3. Mean comparison of different levels of the treatments on fruit and leaf chlorophyll of date palms during the biennium.

Treatment	Mean comparisons					
	Fruit			Leaf		
	chl a	chl b	chl t	chl a	chl b	chl t
Mn-2	2.02ab	0.715c	2.74ab	7.73g	1.77c	9.506d
Cu-2	2.23a	1.10ab	3.33a	12.43ab	3.85ab	16.32ab
Zn-2	2.01ab	1.11ab	3.35a	10.08d	3.42b	13.5b
Ca-4	1.78ab	0.69c	2.47b	14.36a	4.05ab	18.41a
K-5	1.16e	0.460c	1.64c	11.01c	4.13ab	15.06b
Mn-4	1.60c	0.76b	2.36b	11.8b	4.02ab	15.83ab
Cu-4	1.62b	0.77b	2.56b	10.73c	4.40ab	15.01b
Zn-4	1.50c	0.59c	2.11b	13.64ab	5.01a	18.65a
Ca-6	1.72ab	0.83b	2.55b	9.5e	3.45b	13.12bc
K-7	2.14ab	1.28a	3.43a	9.26e	4.02ab	13.3b
C	1.35d	0.82b	2.17b	8.50f	3.24b	11.72c

Mean values in each column with the same letter are not significantly different at the 5% level based on Duncan's test, whereas values with different letters are significant.
Mn-2: Manganese amino chelate (2 ppm); Cu-2: Copper amino chelate (2 ppm); Zn-2: Zinc amino chelate (2 ppm); Ca-4: Calcium amino chelate; (4 ppm); K-5: Potassium amino chelate (5 ppm); Mn-4: Manganese amino chelate (4 ppm); Cu-4: Copper amino chelate (4 ppm); Zn-4: Zinc amino chelate (4 ppm); Ca-6: Calcium amino chelate (6 ppm); K-7: Potassium amino chelate (7 ppm); C: Control with no foliar spraying.

Among them, potassium-containing treatments had greater effects, such that the foliar application of potassium sulfate alone and in combination with trace elements, through soil application, caused a decrease in the percentage of dried bunches from 69% (in the control group) to 19.7% and 21.2%, respectively. Also, this reduced the percentage of dried fruits from 66.5% (in the control) to 7.5% and 10.4%, respectively, while increasing the fruit yield to 46% and 65%, respectively. The results of the current study showed that certain amino chelates increased the seed weight and seed length (Table 1), which confirm relevant results by other researchers (Naseri et al., 2013). From a cellular perspective, the treatments may increase cell division, elongation, and carbohydrate accumulation in the form of starch grains and fat in the seeds (Tayad et al., 2019; Souri, 2016; Kozlowski, 1992). Some treatments reduced the seed length and seed weight (Table 1), thereby contributing to marketability. Large seeds in date fruits are an undesirable feature and, thus, the correct use of amino chelates can decrease the seed size and the flesh/seed ratio of date fruits (Naseri et al., 2013). A negative relationship was observed between amino chelate treatments and fruit TSS (Table 1). In previous research, a negative relationship was found between the levels of K and TSS in fruits of the 'Kabkab' date palm (Alhejjaj and Ayad, 2018; Abdi and Hedayat, 2010). In the current study, all experimental treatments increased the moisture content of 'Mazafati' date fruits compared to the control group. Loss of moisture and the drying of fruits were caused by the incidence of bunch fading disorder which reduced the fruit yield of date palm trees. A higher moisture content of fruits is a merit for the 'Mazafati' cultivar, which is known for the softness of the fruit texture. While amino chelates increased the quality and moisture of fruits in a previous research as well (Souri, 2016), the current results showed that foliar-spraying trees with experimental treatments of amino chelates increased the concentrations of potassium, calcium, manganese, and magnesium in the leaves, while also increasing the concentrations of potassium, calcium, manganese, magnesium, iron, and boron in fruits of the 'Mazafati' cultivar, compared to the control group (Table 2). The foliar application of three different amino chelates, namely, Fe, Zn- and multimineral-amino acid chelates, caused a significant increase in the Fe concentrations of the leaf (112%), while Zn, Mn, and Cu caused an increase of 64% in the fruit yield of 'Williams' pear (Koksal et al, 1999). The foliar spraying of wheat cultivars with certain Zn-amino acid chelates, including Zn-arginine, Zn-glycine, and Zn-histidine under field conditions, showed that Zn, Fe, and protein concentrations in wheat grain were, on average, 14.3% higher in wheat plants sprayed with zinc amino chelates than those sprayed with $ZnSO_4$ (Ghasemi et al., 2013). Amino chelates of manganese, copper, zinc, calcium and potassium increased the chlorophyll content in the leaves and fruits. Garcia et al. (2011) reported that using amino acids increased the chlorophyll concentration and delayed leaf senescence. The results of similar research indicated how amino chelates can enhance the chlorophyll content (Jie et al., 2008; Souri, 2016). Proper nutritional management of date palms can lead to high fertility and quality fruit production. One of the limitations of adding nutrients to the soil is the salinity or alkalinity of soils in most areas under date cultivation, although modifying the methods of application may increase fruit yield. Generally, amino chelates were effective in reducing the bunch fading disorder significantly and in improving fruit quality and quantity. The results of this research on date palm can be a solution for the serious problem of bunch fading disorder in regions where date cultivation is susceptible to serious loss.

Conclusion

Based on the results obtained from the present study, foliar spraying the 'Mazafati' cultivar with amino chelates of manganese, copper, zinc, calcium and potassium effectively reduced the bunch fading disorder and the damage caused thereof. These treatments increased the fruit yield, fruit moisture, chlorophyll content in the leaves and fruits, and the concentration of elements in the leaves and fruits, compared to the control group. This was the first experiment on nutrient amino chelates and their effects on bunch fading disorder in the 'Mazafati' cultivar. It is suggested that additional experiments be performed through different doses on other sensitive cultivars.

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Conflict of interest
The authors indicate no conflict of interest in this this work.

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