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IMPACT OF CLIMATIC CHANGES ON SAFFLOWER (*Carthamus tinctorius* L.) PRODUCTIVITY: IMPROVING GROWTH AND CARTHAMIN PIGMENT CONTENT BY SOWING DATE ADAPTATION AND MICRONUTRIENTS FOLIAR APPLICATION

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ABSTRACT

The current Investigation was conducted to assess the effect of three sowing dates (October, November and December) and the foliar application of Fe, Mn and Zn and their combinations on growth, flowering and carthamin content of safflower plant. All plant characteristics were significantly affected by sowing dates and micronutrients application. Better growth and higher carthamin content appeared to be more closely related to earliness of planting as October favored the best results. As sowing date was delayed, significant reductions in all plant growth characteristics were noticed. Fe and/or Mn positively affected plant height, branch number/plant, head number/plant and plant fresh weight. However, plant dry weight and petals dry weight/plant had the highest values in Zn-treated plants. Petals content of carthamin recorded the highest values when plants were sprayed with Fe alone or in combination with both Zn and Mn during either October or November. Accordingly, it is recommended that safflower plant is preferably planted in October; otherwise any delay in sowing date will severely affect its yield and quality. To ensure better growth and higher yield of carthamin, a foliar application of Fe at 300 ppm or its combination with Mn at 200 ppm and Zn at 150 ppm is recommended.

Keywords: Safflower red, climate change, sowing date, Iron, Manganese, Zinc

INTRODUCTION

Safflower (*Carthamus tinctorius* L.), a member of family Asteracea (Compositae), is one of the world's oldest crops probably originated from southern Asia and is known to have been cultivated in Egypt in addition to China, India and Iran almost from prehistoric times. It is a highly branched, herbaceous annual herb with yellow to red petals (Bae *et al.*, 2002). In addition to being famous as an oilseed crop, dye from safflower had been used in Egypt to color cotton and silk as well as ceremonial ointment used in religious ceremonies and to anoint mummies prior to binding. Safflower seeds and packets, and garlands of florets have been found with 4000-year-old mummies (Weiss, 1971). The colour of flower varies from whitish yellow to red orange with deep yellow being the most common. Safflower flowers contain two pigments viz. red (carthamin) which is insoluble in water and yellow (carthamidin) which is soluble in water and mainly used as a material for dye and is currently being used as a natural food colorant (Wouters *et al.*, 2010). Other uses of its flowers have also mentioned as cut flowers, making herbal teas and medicinal purposes (Emongor, 2010). Despite the many uses of safflower, it has remained a minor crop. Therefore, it is essential to carry out research on this crop and to popularize it as a commercial crop for development of its application as a natural source of eco-friendly and biodegradable dyes, which have emerged as important alternatives to synthetic dyes. (Obara and Onodera, 1979; Emongor, 2010).

Safflower is a warm temperature crop, cultivated over the greater parts of tropical Asia, Africa, Russia and China (Wouters *et al*., 2010). It's deep taproot and greater ability to withstand higher temperatures compared to other winter crops has also enabled it to be grown as a promising crop on hot and dry atmosphere (Armstrong, 1981). There are many factors affect yield components of safflower including genotype, environmental conditions and cultural practices. Sowing date has an expresser influence and therefore determining the appropriate sowing date is one of the most critical factors for optimizing safflower productivity (Khajehpour, 1998; Yau, 2007). The choice of the appropriate sowing date is one of the key points in crop management, and suggestion of such dates to farmers increases their yield, profit and also their tendency to cultivate a specific crop as safflower (Badri *et al.,* 2012). Several studies conducted in different parts of the world have shown that safflower could be grown as a winter crop in areas with mild weather or as a spring crop in cooler areas, although seed yield of autumn-sown plants significantly surpasses spring-sown ones (Koutroubas, *et al*. 2004; Yau, 2007). Planting safflower in northern Egypt during October was shown by Abou-Dahab *et al.* (2014) to be the best sowing date comparing with spring dates for producing the tallest plants, the greatest number of branches, the largest number of flowers as well as the highest phosphorus and potassium percentages. Even in other Mediterranean regions, it was reported that seed yield and oil content were decreased with the delay in sowing date (Samanci and Ozkaynak, 2003). The same fact was supported by the findings of Khalil1 *et al*. (2013) who indicated that earlier sowing date gave the highest yield. Therefore, adapted crop sowing date estimation seems crucial for arid areas such as in Egypt.

Significance of micronutrients on vast varieties of plant systems have been investigated by many authors who emphasized that foliar or soil application of micronutrients positively affects plant growth in which many biologically important processes are involved. Contributive effect of iron on the vegetative growth and flowering of safflower plant was reported, indicating that iron application enhances carthamin formation in florets of safflower. The deficiency of micronutrients is widespread due to cultivation of high yielding varieties, intensive agriculture and decrease in the use of organic manures. This necessitates the application of micronutrients as they have becoming limiting factor for obtaining higher yields of several oil seed crops including safflower (Ravi *et al.*, 2008). In arid and semiarid regions such as Egypt, foliar application of nutrients has many advantages comparing with soil fertilization including quick compensation of nutrient deficiency particularly when it is difficult for roots to provide necessary nutrients. Employing of less rates in foliar application helps reduce toxicity of excessive elements accumulation and prevents nutrients fixation in the soil fertilization where they are adsorbed on the soil particles and became less available to the rooting medium (El-Fouly *et al*., 2002)

Therefore, keeping these aspects in view, a field experiment was conducted to study the most adequate sowing date along with the efficacy of foliar application of iron, zinc and magnesium on growth, flowering and carthamin content in safflower.

MATERIALS AND METHODS

A field experiment was conducted during the two successive seasons of 2013/2014 and 2014/2015 at the Floriculture Experimental Farm, Faculty of Agriculture, Assiut University, Assiut, Egypt.

Seeds of safflower cv. Giza-1 were obtained from Oil Crops Research Department, Agric. Res. Center. Iron (Fe), manganese (Mn) and zinc (Zn) were used in the form of EDTA chelate (13%) produced by Nature SA, Greece. The maximum and minimum temperature as well as the relative humidity of the experimental location which were obtained from the Meteorological Station at the Experimental Farm, Faculty of Agriculture, Assiut University are presented in Table (1). The soil physical and chemical characteristics of the experimental field which were done according to the methods described by Black *et al*. (1982) and Jackson (1973) are shown in Table (2).

Table (1). Monthly average of metrological data of the experimental farm during 2013, 2014 and 2015 years.

Months	2013				2014				2015			
	Temperature C°		Humidity %		Temperature C°		Humidity %		Temperature C°		Humidity %	
	max	min	max	min	max	min	max	min	max	min	max	min
Jan	22.2	7.0	92.1	44.3	20.0	3.8	87.9	41.7	22.2	7.0	87.8	43.0
Feb	25.4	8.6	84.3	34.7	22.4	6.9	79.4	35.7	25.5	8.0	84.1	36.6
Mar	27.6	9.3	76.8	28.2	26.0	8.2	81.4	32.2	30.6	11.7	79.4	29.6
Apr	31.2	13.1	71.8	24.4	34.1	15.3	65.4	22.5	31.5	13.6	72.2	26.9
May	35.9	18.2	59.4	19.9	37.9	19.0	58.5	19.3	39.2	20.0	57.8	18.4
Jun	38.7	21.9	56.6	19.5	53.3	22.4	60.3	19.6	40.4	22.6	56.8	22.0
Jul	40.4	23.4	61.3	19.8	40.4	24.2	64.9	24.7	37.1	23.2	73.2	29.5
Aug	38.8	22.0	65.2	27.1	39.1	22.8	69.4	27.8	38.2	22.3	69.2	29.5
Sep	33.1	19.7	68.0	27.9	36.3	20.3	77.7	31.9	36.9	20.9	78.1	32.3
Oct	33.1	16.5	70.7	29.3	36.0	18.0	77.5	30.2	32.1	25.6	79.4	33.9
Nov	26.2	10.2	82.4	35.5	29.8	14.2	83.5	38.6	29.4	14.3	82.4	39.2
Dec	22.8	7.0	91.1	41.4	23.3	8.0	92.3	45.5	22.7	8.3	84.7	42.7

Table (2). Characteristics of the clay soil used at the beginning of the experiment (average of both seasons)

Particle size distribution (%)				pH (1:2.5) soil suspension	EC. dS /m (1:5) soil extract	Total CaCO3 (%)	Organic matter (%)	Soluble ions (meq/l, soil paste)								Total N (%)	Total P (%)	Total K (%)
								Anions				Cations						
Sand	Silt	clay	Texture grade					Cl^-	$CO_3^=$	HCO_3^-	$SO_4^=$	Ca^{++}	Mg^{++}	Na^+	K^+			
22.3	26.20	51.50	Clay	8.71	1.03	1.97	0.97	3.32	-	4.94	3.05	5.40	0.52	1.30	3.89	0.70	0.21	0.41

Citric acid and acetone used for carthamin determination were analytical grade from El-Nasr Co. for Intermediate Chemicals, Egypt (NCIC). Cellulose powder was produced by S.D. Fine-Chem Limited, India.

The experiment was laid out in a split-plot design based on a randomized complete block design (RCBD) with three replications. The main plots were presented by three sowing dates (October 5th, November 5th and December 5th), and the sub-plots comprised eight levels of the combinations among Fe (300 ppm), Mn (200 ppm) and Zn (150 ppm) viz; Fe, Mn, Zn, Fe+Mn, Fe+Zn, Mn+Zn, Fe+Mn+Zn and the control (tap-water). Plot size was 2 x 1.5m comprising 3 rows 60cm apart. Seeds of safflower were sown by hand at 30cm in row, three seeds in each hole and were thinned on two plants. Foliar sprays of micronutrients were applied three times; one month after planting and repeated two more times at three-weeks interval. Random samples were taken from plants of the middle of the plot and data were recorded on: plant height (cm), branch number/plant, head number/plant, plant fresh and dry weights (g), petals dry weight/plant (g), heads dry weight/plant (g) and seeds dry weighed/plant, in addition to carthamin (safflower red dye) content in florets. All agricultural practices such as soil preparation, seed sowing, irrigation, thinning, weed control and harvesting were done as recommended during both seasons.

Determination of carthamin content in the florets:

Florets were collected, air-dried in shade and used for the estimation of carthamin content. Extraction of carthamin was done as described previously by Kulkarni *et al*. (1997) with some modifications suggested by Fatahi *et al*. (2008). One gram of fine dry floret powder was suspended in 20ml of 0.5% w/v sodium carbonate. The mixture was stirred for 30min at room temperature and the floating pieces were then removed by centrifugation at 3500 rpm for 15min. The supernatant was retained at 5°C and the resulting suspension was subjected to the same process two more times. The cooled supernatant from the three times was mixed together and acidified with 0.5% citric acid. To adsorb carthamin from acid extract, cellulose powder (0.5 g) was suspended in each sample, stirred for 30 min at room temperature and centrifuged at 3500 for 15 min. Supernatant was discarded and the pellet was suspended in a distilled water and centrifuged. Washing with distilled water was repeated 5-6 times until colorless supernatant was obtained. The pellet was suspended in 10 ml of acetone, mixed and then centrifuged for 5 min at 3500 rpm. The acetone layer was filtered and used for spectrophotometric measurement of carthamin at 520 nm.

Data was subjected to statistical analysis using "F" Test (Snedecor and Cochran 1989) and L.S.D. value for comparison between means of treatments according to Steel and Torrie (1982). Statistical analysis was performed using Statistix 8.1 program.

RESULTS

Data presented in Tables (3, 4 and 5) show that sowing date had a significant influence on plant height, branch number/plant, plant fresh and dry weights and carthamin content in both growing seasons, as well as head number/plant, petals dry weight/plant, heads dry weight/plant, seeds dry weight/ plant in the first season only. Among the three sowing dates tested, the earliest date (October) recorded the best results regarding all safflower growth, yield and carthmain dye content characteristics. Plants grown in November significantly surpassed those grown in December in almost all parameters. Plants grown in October reached 177.7 and 173.5 cm height, in both seasons respectively, and were characterized by more branches (11.6 and 10.6). Differences in plant fresh and dry weights were spectacular where October-grown plants weighed from two to three fold of those grown in either later dates. Flowering characteristics, as an important yield determining trait for safflower, were significantly improved by early sowing date. October sowing date induced significantly higher head number (64.1 and 62.7), heads dry weight/plant (146.5 and 117.4 g) and petals dry weight/plant (6.4 and 4.1g), in both seasons, respectively. A similar effect was also noticed in seed yield as inferred from seeds dry weight/plant and petals dry weight/plant in the first season. Petals content of carthamin reached 4 mg/g in October-grown plants comparing with 3.6 and 1.5 in November and December-grown plants in the first season, respectively. A similar trend was detected in the second season.

Foliar application of micronutrients exhibited significant effect on plant height, branch number/plant, head number/plant, plant fresh and dry weights, petals dry weight/plant and carthamin content. Meanwhile, no significant effects were noticed in heads dry weight/plant and seeds dry weight/plant in both growing seasons. Although plant height significantly differed according to fertilization treatment, the differences among most of the treatments were still in a narrow range. Combination of Fe, Mn and Zn exhibited the best results followed by either the sole Fe or Mn treatment or their combination with no significant differences among them in the second season. The same treatments in the same order similarly affected branch number/plant, head number/plant and plant fresh and dry weights. Application of either Zn alone or in combination with Fe showed significant superiority to other treatments in terms of heads dry weight/plant, petals dry weight/plant and seed dry weight/plant. Fe alone or in combination with both Zn and Mn showed the highest content of carthamin in both seasons recording almost three fold of that noticed in the control treatment.

Both foliar application of micronutrients and sowing date significantly interacted with respect to all characteristics of safflower plants in both seasons except for heads dry weight and seed dry weight/plant. The best results were noticed in October-grown plants treated with the combination of the three nutrient elements in most parameters. Fe and/or Mn positively affected plant height, branch number/plant, head number and plant fresh weight. However, plant dry weight and petals dry weight/plant had the highest values in Zn-treated plants. Safflower content of carthamin recorded its highest values when plants were sprayed with Fe alone or in combination with both Zn and Mn during either October or November.

Table (3). Effect of different sowing dates and foliar micronutrient applications on plant height, branch number/plant and head number/plant of safflower during 2013/2014 and 2014/2015 seasons.

Sowing dates	Micronutrients	Plant height (cm) Seasons		Branch number/ plant Seasons		Head number/ plant Seasons	
		2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015
October	Control	164.3	150.0	9.3	8.4	51.1	46.7
	Fe	179.0	175.0	12.5	11.6	66.5	65.3
	Mn	180.3	178.3	14.4	12.8	75.3	73.7
	Zn	172.3	170.3	10.6	10.0	63.3	59.0
	Fe+Mn	185.7	182.3	11.1	10.5	55.7	58.3
	Fe+Zn	178.3	176.0	10.2	9.3	61.1	60.7
	Mn+Zn	171.0	169.0	12.6	10.5	64.7	62.7
	Fe+Mn+Zn	190.3	186.7	12.1	11.9	75.0	75.3
Mean		177.7	173.5	11.6	10.6	64.1	62.7
November	Control	136.3	128.0	7.3	6.2	35.7	35.7
	Fe	154.0	150.3	11.2	10.0	43.2	43.7
	Mn	152.0	149.7	11.0	10.7	50.0	51.0
	Zn	143.0	140.0	9.6	9.7	43.0	42.0
	Fe+Mn	154.0	147.3	10.7	10.3	48.0	47.6
	Fe+Zn	150.0	144.3	10.9	10.6	44.3	44.3
	Mn+Zn	143.5	142.3	9.9	10.0	52.5	51.7
	Fe+Mn+Zn	157.0	154.3	11.1	11.7	60.5	59.7
Mean		148.7	144.5	10.2	9.9	47.2	47.0
December	Control	123.5	122.7	8.8	8.9	26.3	31.3
	Fe	133.5	137.7	10.8	11.0	41.0	42.0
	Mn	138.0	138.7	9.7	9.9	41.5	41.3
	Zn	128.0	126.0	10.3	10.7	31.0	33.3
	Fe+Mn	135.5	139.7	9.6	9.9	39.0	40.0
	Fe+Zn	132.0	133.0	9.6	9.7	29.0	31.3
	Mn+Zn	131.0	135.0	11.6	10.5	43.0	43.0
	Fe+Mn+Zn	141.5	145.0	11.5	12.5	53.5	52.0
Mean		132.9	134.7	10.2	10.4	38.0	39.3
Means of micro-nutrient treatments	Control	141.4	133.6	8.5	7.8	37.7	37.9
	Fe	155.5	154.3	11.5	10.9	50.2	50.3
	Mn	156.8	155.6	11.7	11.1	55.6	55.3
	Zn	147.8	145.4	10.2	10.1	45.8	44.8
	Fe+Mn	158.4	156.4	10.5	10.2	47.6	48.6
	Fe+Zn	153.4	151.1	10.2	9.9	44.8	45.4
	Mn+Zn	148.5	148.8	11.4	10.3	53.4	52.4
	Fe+Mn+Zn	162.9	162.0	11.6	12.0	63.0	62.3
LSD 0.05	Dates	1.35	3.36	1.15	NS	4.83	4.69
	Fertilization	1.24	2.66	0.89	0.62	3.70	3.87
	Interaction	2.14 (2.40)*	4.60 (5.40)	1.54 (1.82)	1.07 (1.21)	6.42 (7.62)	6.71 (7.54)

*** LSD values to compare the means under the same level of sowing date, and values between parentheses to compare the means under different levels of sowing date.**

Table (4). Effect of different sowing dates and foliar micronutrient applications on plant fresh weight, plant dry weight and heads dry weight/plant of safflower during 2013/2014 and 2014/2015 seasons.

Sowing dates	Micronutrients	Plant fresh weight (g) Seasons		Plant dry weight (g) Seasons		Heads dry weight (g/plant) Seasons	
		2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015
October	Control	700.0	683.3	189.7	171.7	112.5	120.2
	Fe	782.0	809.7	259.7	244.5	136.6	129.9
	Mn	890.0	893.0	251.0	246.4	178.3	173.7
	Zn	808.7	783.0	268.7	271.1	164.6	172.0
	Fe+Mn	890.7	886.7	229.3	221.7	153.5	160.7
	Fe+Zn	900.0	897.7	257.7	255.7	148.1	134.2
	Mn+Zn	913.3	893.3	277.0	273.7	138.0	136.9
	Fe+Mn+Zn	953.7	949.3	273.1	276.1	167.9	154.1
Mean		854.8	849.5	250.8	245.1	149.9	147.7
November	Control	234.7	232.0	76.8	72.2	72.4	72.5
	Fe	276.0	276.0	124.3	132.7	94.7	93.0
	Mn	273.0	274.0	148.5	148.0	107.7	106.7
	Zn	268.5	275.3	136.5	136.3	90.7	93.1
	Fe+Mn	331.0	333.3	152.5	153.0	79.5	82.3
	Fe+Zn	319.5	326.0	164.3	162.0	80.5	84.1
	Mn+Zn	341.0	348.3	167.7	152.7	105.4	405.9
	Fe+Mn+Zn	345.0	383.3	150.7	155.0	99.5	104.7
Mean		298.6	306.0	140.2	139.0	91.3	130.3
December	Control	134.0	149.3	71.0	69.3	38.3	37.7
	Fe	232.0	230.2	95.5	93.0	47.2	48.3
	Mn	221.5	222.0	101.0	107.8	55.3	54.3
	Zn	189.0	182.3	107.0	109.1	45.0	44.0
	Fe+Mn	233.3	229.5	117.5	115.9	59.1	61.7
	Fe+Zn	238.5	237.3	104.7	105.0	55.0	56.0
	Mn+Zn	290.0	279.3	113.5	111.3	63.1	62.0
	Fe+Mn+Zn	279.7	280.3	129.0	132.2	73.5	78.1
Mean		227.3	226.3	104.9	105.5	54.6	55.3
Means of fertilization treatments	Control	356.2	354.9	112.5	104.4	74.4	76.8
	Fe	430.0	438.6	159.8	156.7	92.8	90.4
	Mn	461.5	463.0	166.8	167.4	113.8	111.6
	Zn	422.1	413.6	170.7	172.2	100.1	103.0
	Fe+Mn	485.0	483.2	166.4	163.5	97.4	101.6
	Fe+Zn	486.0	487.0	175.6	174.2	94.5	91.4
	Mn+Zn	514.8	507.0	186.1	179.2	102.2	201.6
	Fe+Mn+Zn	526.1	537.6	184.3	187.8	113.6	112.3
LSD 0.05	Dates	43.05	44.95	12.70	10.54	6.53	NS
	Fertilization	32.78	32.14	8.13	13.66	8.42	NS
	Interaction	56.78 (67.61)	55.66 (67.99)	28.42 (29.28)	23.65 (24.36)	14.58 (15.03)	NS

*** LSD values to compare the means under the same level of sowing date, and values between parentheses to compare the means under different levels of sowing date.**

NS denotes non-significant differences at *p*=0.05 by LSD.

Table (5). Effect of different sowing dates and foliar micronutrient applications on petals dry weight, seeds dry weight and carthamin content of safflower plants during 2013/2014 and 2014/2015 seasons.

Sowing dates	Micronutrients	Petals dry weight/plant (g)		Seeds dry weight (g/plant)		Carthamin content (mg/g)	
		Seasons		Seasons		Seasons	
		2013/2014	2014/2015	2013/2014	2014/2015	2013/2014	2014/2015
October	Control	5.3	2.9	31.7	32.7	2.28	2.39
	Fe	7.3	4.5	55.9	56.7	6.09	6.47
	Mn	8.1	4.6	85.9	80.0	2.57	3.01
	Zn	8.2	4.4	66.3	64.7	3.93	5.95
	Fe+Mn	6.4	4.5	66.5	66.7	4.82	4.19
	Fe+Zn	5.9	3.7	59.7	61.0	2.54	2.68
	Mn+Zn	5.5	4.2	87.0	84.7	3.92	3.53
	Fe+Mn+Zn	4.6	3.6	81.4	81.0	5.83	8.35
Mean		6.4	4.1	66.8	65.9	4.0	4.6
November	Control	2.5	1.8	21.5	22.4	1.55	1.19
	Fe	3.2	2.9	33.5	28.7	6.39	5.20
	Mn	2.9	4.1	43.2	34.9	1.69	1.62
	Zn	3.6	3.1	26.0	25.4	2.52	2.58
	Fe+Mn	3.3	3.1	40.1	39.3	3.37	2.35
	Fe+Zn	3.5	3.1	31.9	31.8	3.09	2.75
	Mn+Zn	2.9	3.4	46.0	39.7	3.95	3.30
	Fe+Mn+Zn	2.4	3.2	47.0	48.1	6.17	5.60
Mean		3.0	3.1	36.1	33.8	3.6	3.1
December	Control	2.1	3.0	18.0	16.2	0.84	0.93
	Fe	2.7	5.0	21.6	22.9	2.19	2.14
	Mn	3.2	3.9	29.5	30.1	0.92	0.78
	Zn	3.1	4.3	19.1	18.7	1.33	0.96
	Fe+Mn	2.7	4.3	24.2	24.9	1.34	1.52
	Fe+Zn	1.9	4.6	25.0	22.7	1.62	2.21
	Mn+Zn	2.8	5.3	31.7	29.1	1.37	1.53
	Fe+Mn+Zn	2.7	4.0	35.2	31.3	2.26	2.89
Mean		2.6	4.3	25.5	24.5	1.5	1.6
Means of fertilization treatments	Control	3.3	2.6	23.7	23.8	1.6	1.5
	Fe	4.4	4.1	37.0	36.1	4.9	4.6
	Mn	4.7	4.2	52.9	48.3	1.7	1.8
	Zn	5.0	3.9	37.1	36.2	2.6	3.2
	Fe+Mn	4.1	4.0	43.6	43.6	3.2	2.7
	Fe+Zn	3.8	3.8	38.9	38.5	2.4	2.5
	Mn+Zn	3.7	4.3	54.9	51.1	3.1	2.8
	Fe+Mn+Zn	3.2	3.6	54.5	53.5	4.8	5.6
LSD 0.05	Dates	0.49	NS	6.99	7.69	0.39	0.38
	Fertilization	0.76	0.77	3.74	3.69	0.39	0.20
	Interaction	1.31 (1.31)	NS	6.48 (9.13)	6.40 (9.62)	0.67 (0.74)	0.35 (0.50)

*** LSD values to compare the means under the same level of sowing date, and values between parentheses to compare the means under different levels of sowing date.**
NS denotes non-significant differences at *p*=0.05 by LSD.

DISCUSSION

The current study assessed the impact of changing sowing date on safflower growth and carthamin content in conjunction with foliar application of the different micronutrient combinations. The results showed a significant effect of sowing date on plant growth characteristics which were highly improved by early sowing date in October. As sowing date was delayed, all growth characteristics were significantly and negatively affected. It is clear that the effect of sowing date is associated with changes in climatic parameters such as temperature and humidity which appear in Table (1). Optimum climatic condition in October led to the improvements noticed in growth characteristics of safflower. Nevertheless, assessment of crop growth and productivity in other sowing dates is very helpful under such vulnerability to climatic changes we live nowadays. Several studies conducted in different parts of the world have shown that safflower sown in autumn produces significantly higher seed yield over those sown in spring (Koutroubas, *et al*. 2004; Yau, 2007). Sowing in October was shown by Abou-Dahab *et al*. (2014) to be the best sowing date for safflower in northern Egypt comparing with spring dates for producing the tallest plants, the greatest number of branches, the largest number of flowers and the highest percentages of phosphorus and potassium. Even in other Mediterranean regions, it was reported that seed yield and oil content were decreased with the delay in sowing date (Samanci and Ozkaynak, 2003). The same fact was supported by the findings of Khalil1 *et al*. (2013) who indicated that earlier sowing date gave higher yield. Therefore, adapted crop sowing date estimation seems crucial for arid areas such as Egypt.

Foliar application of Fe, Mn and Zn had significant positive effect on yield and quantitative parameters of safflower comparing to the control. Among the micronutrient treatments, application of Fe, Mn and their combination improved most of the vegetative growth characteristics, meanwhile Zn was involved in the enhancement of heads and petals dry weight. Fe appeared also significantly effective in improving carthamin content. Plants receiving Fe and/or Mn might have been helped in terms of vigorous root growth, formation of chlorophyll, resulting in higher photosynthesis and protein which might have resulted in better growth and higher dry matter production. The importance of Iron is clear for chlorophyll formation and photosynthesis and is important in the enzyme systems and respiration of plants (Tariq *et al*., 2004). Zinc exerts a great influence on basic plant life processes, such as nitrogen metabolism–uptake of nitrogen and protein quality, and photosynthesis–chlorophyll synthesis, carbon anhydrase activity (Potarzycki and Grzebisz, 2009). Zinc is also known to have an important role either as a metal component of enzymes or as a functional, structural or regulatory cofactor of enzymes (Grotz and Guerinot, 2006). Manganese in turn takes part in photosynthesis and is known as an activator of many different enzymatic reactions. Manganese activates decarboxylase and dehydrogenase and is a constituent of complex PSII-protein, SOD (superoxide dismutase enzyme) and phosphatase. Deficiency of Mn leads to inhibition of growth, chlorosis and necrosis, early leaf fall and low reutilization (Kabata-Pendias and Pendias, 1999). The results of the current investigation are in consonance with the findings of Ravi, *et al*., (2008) and references therein). This beneficial effect might be due to the interaction of nutrients and their role in the synthesis of IAA, metabolism of auxin and formation of chlorophyll synthesis as reported by Rathore and Tomar (1990). These results are in agreement with the findings of Venkatesh *et al*. (2002) who indicated that incorporation of Fe and Zn in foliar fertilization treatment improves seed yield. They attributed this effect to the involvement of zinc and iron in enzyme activity in plant cell. These results are also in accordance with those of Kohnaward *et al*. (2012) indicating that foliar application of Zn and Mn had significant positive effect on yield and quantitative parameters of safflower. Babaeian *et al*., (2011) also reported an increase in growth, yield and oil content of sunflower as a response to micronutrients application. Kubsad *et al*. (2010) concluded that incorporation of $ZnSO_4$ in combinations of fertilizers induced higher safflower seed yield. It is clear from the above mentioned discussion that safflower plant is preferably planted in October, otherwise any delay in sowing date will severely affect its yield and quality. To ensure better growth and high yield of carthamin, a foliar application of Fe, Mn and Zn is recommended.

REFERENCES

Abou-Dahab A. M.; Habib A. M. and Saleh S. M. (2014) Effect of sowing dates, organic and chemical fertilization on growth, flowering and the chemical composition of *Carthamus tinctorius* L. plants J. Hort. Sci. & Ornamen. Plants, 6 (2): 71-81.

Armstrong E.L. (1981). Sowing time effects on yield, components of yield and development of irrigated safflower in the central West of New South Wales. Proceeding of The First International Safflower Conference, the University of California, Davis, July 12 to 16, p: 3-8.

Babaeian M.; Piri I.; Tavassoli A.; Esmaeilian Y. and Gholami H. (2011) Effect of water stress and micronutrients (Fe, Zn and Mn) on chlorophyll fluorescence, leaf chlorophyll content and sunflower nutrient uptake in Sistan region. Afr J Agric Res, 6(15): 3526-3531.

Badri A.R.; Shirani Rad A.H.; Zadeh S.S. and Bitarafan Z. (2012). Sowing date effect on spring safflower cultivars. International Archive of Applied Sciences and Technology, 3: 26-32.

Bae C.S.; Park C.H.; Cho H.J.; Han H.J.; Kang S.S.; Choi S.H., and Uhm C.S. (2002). Therapeutic effects of safflower (*Carthamus tinctorius* L.) seed powder on osteoporosis. Korean J. Electron. Microscopy, 32: 285-290.

Black C.A.; Evans D.D.; White J.I.; Ensminger L.E. and Clark F.E. (1982). Methods of Soil Analysis. American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin, USA.

El-Fouly M.M.; Mobarak Z.M. and Salama Z.A. (2002). Micronutrient foliar application increases salt tolerance of tomato seedlings. Proc. Symp. Techniques to Control Salination for Horticultural Productivity. Acta Hort., 573: 377-385.

Emongor V. (2010) Safflower (*Carthamus tinctorius* L.) the underutilized and neglected crop: A review. Asian Journal of Plant Sciences, 9 (6): 299-306.

Fatahi N.; Carapetian J. and Heidari R. (2008). Spectrophotometric measurement of valuable pigments from petals of safflower (*Carthamus tinctorius* L.) and their identification by TLC method. Research Journal of Biological Sciences, 3: 761-763.

Grotz N. and Guerinot M.L. (2006). Molecular aspects of Cu, Fe and Zn homestasis in plants. Biochim. Biophys Acta., 1763(7): 595-608.

Jackson M.L. (1973). Soil Chemical Analysis. Prentic-Hall. Inc. Englewood, Cliffs, USA.

Kabata- Pendias A. and Pendias H. (1999). Biogeochemistry of Trace Elements. PWN, WarSaw, Poland.

Khajehpour M.R. (1998). Production of Industrial Crops. Publications Jihad, Unit University of Technology of Isfahan. Fourth edition, 274 (in Persian).

Khalil1 N.A; Dagash Y.M; and Yagoub S.O. (2013) Effect of sowing date, irrigation intervals and fertilizers on safflower (*Carthamus tinctorius* L.) yield. Discourse Journal of Agriculture and Food Sciences, 1 (5): 97-102.

Kohnaward P.; Jalilian J. and Pirzad A. (2012). Effect of foliar application of micro-nutrients on yield and yield components of safflower under conventional and ecological cropping systems. International Research Journal of Applied and Basic Sciences, 3 (7): 1460-1469.

Koutroubas, S.D.; Papakosta D.K. and Doitsinis A. (2004). Cultivar and seasonal effects on the contribution of pre-anthesis assimilates to safflower yield. Field Crop Research, 90: 263-274.

Kulkarni DN, SM Revanwar, KD Kulkarni and HW Deshpabde (1997) Extraction and uses of natural pigments from safflower florets. 4th Int. Safflower Conf., Italy, p: 365-368.

Kubsad, V. S.; Nekar, M. M. and Hulihalli, U. K. (2010). Productivity of safflower (*Carthemus tinctorius* L.) with micronutrient application under rainfed conditions in Vertisols. Current Advances in Agricultural Sciences; 2 (2): 118-119.

Obara H. and Onodera J. (1979) Structure of carthamin. Chem Lett 201-204.

Potarzycki J. and Grzebisz W. (2009). Effect of zinc foliar application on grain yield of maize and its yielding components. Plant Soil Environ., 55(12): 519-527.

Rathore D.S. and Tomar S.S. (1990). Effect of sulphur and nitrogen on seed yield and nitrogen uptake by mustard. Ind. J. Agron., 35(4):361-363

Ravi S.; Channal H. T.; Hebsur N. S.; B. N. Patil and Dharmatti P. R. (2008) Effect of Sulphur, Zinc and Iron Nutrition on Growth, Yield, Nutrient Uptake and Quality of Safflower (*Carthamus tinctorius* L.). Karnataka J. Agric. Sci., 21(3):382-385.

Samanci B. and E. Ozkaynak, (2003). Effect of planting date on seed yield, oil content and fatty acid composition of safflower (*Carthamus tinctorius*) cultivars grown in the Mediterranean region of Turkey. Journal of Agronomy and Crop Science, 189: 359-360.

Snedecor G.W. and Cochran W.G. (1989). Statistical Methods. 8th ed, Iowa State University Press,Ames. Iowa, USA.

Steel R.G. and Torrie T.H. (1982). Principles and Procedures of Statistics. McGraw-Hill International Book Company, 3rd Edn., London.

Tariq, A.; Gill Rahmatullah M.A. and Sabir M. (2004). Mineral Nutrition of Fruit Trees. Proc. Plant-Nutrition Management for Horticultural Crops under Water-Stress Conditions, Agriculture Research Institute, Sariab, Quetta, p: 28-33.

Venkatesh M. S.; Hebsur, N. S. and Satyanarayana, T. (2002), Evaluation of sulphur carriers for safflower in Vertisols of North Karnataka. Karnataka J. Agric. Sci., 15(2): 284-287.

Weiss E.A. (1971). Castor, Sesame and Safflower. Leonard Hill, London, ISBN: 0—85954-137—1

Wouters J,; Grzywacz C.M. and Claro A. (2010) Markers for identification of faded safflower (*Carthamus tinctorius* L.) colorants by HPLC-PDA-MS: Ancient fibers, pigments, paints and cosmetics derived from antique Recipes. Studies in Conservation 55: 186-203.

Yau S.K. (2007). Winter versus spring sowing of rain-fed safflower in a semi-arid, high-elevation Mediterranean environment. European Journal of Agronomy, 26: 249-256.

تأثير التغيرات المناخية على إنتاجية نبات القرطم: تحسين النمو ومحتوى صبغة الكارثامين باختيارموعد الزراعة المناسب والمعاملة بالرش بالعناصر الصغري

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أجريت التجربة الحالية بهدف دراسة تأثير ثلاثة مواعيد للزراعة (أكتوبر ونوفمبر وديسمبر)، والمعاملة بالرش بكل من الحديد (٣٠٠جزء فى المليون) والمنجنيز (٢٠٠جزء فى المليون) والزنك (١٥٠جزء فى المليون) وجميع التوليفات الممكنة بينها على النمو والإزهار ومحتوى صبغة الكارثامين لنبات القرطم. وأظهرت النتائج تأثيرًا معنويًا لمواعيد الزراعة والمعاملة بالعناصر الصغرى على جميع الصفات. وكانت هناك علاقة واضحة بين التحسن في النمو ومحتوى الكارثامين وبين التبكير في الزراعة، حيث أعطت النباتات المنزرعة في أكتوبر أفضل النتائج. وبتأخير مواعيد الزراعة لوحظ تناقصًا معنويًا في جميع صفات النمو للنبات. وأظهرت المعاملة بالحديد والمنجنيز معاً أو كل على حده تأثيرًا إيجابيًا قويًا على ارتفاع النبات، عدد الفروع للنبات، عدد الرؤوس للنبات والوزن الطازج للنبات. في حين كانت أفضل النتائج في الوزن الطازج للنبات والبتلات في النباتات المعاملة بالزنك منفردًا. وتم تسجيل أعلى محتوى لصبغة الكارثامين عند الرش بالحديد منفردًا أو مشتركًا مع كل من الزنك والمنجنيز وذلك في النباتات المنزرعة في أكتوبر أو نوفمبر. بناءً على ذلك، فإنه يوصى بزراعة القرطم في أسيوط مبكرًا في أكتوبر حيث أن تأخير موعد الزراعة يؤثر سلبًا على كمية وجودة المحصول. وللحصول على نمو أفضل ومحصول أعلى من صبغة الكارثامين فإنه ينصح بالرش بالحديد منفردًا أو مشتركًا مع المنجنيز والزنك.