RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
57 (6) 2701-2712, 2025
http://doi.org/10.54910/sabrao2025.57.6.43
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

HUMIC ACID AND PLANT DENSITY EFFECT ON GROWTH, YIELD COMPONENTS, AND QUALITY OF SAFFLOWER (*CARTHAMUS TINCTORIUS* L.)

S.A.M.A. AL-DOORI

Department of Science, College of Basic Education, University of Mosul, Mosul, Iraq
Author's email: saadahmed@uomosul.edu.iq

SUMMARY

In determining the best level of humic acid foliar application and suitable plant density and their effect on growth traits, yield components, and the quality of three safflower (*C. tinctorius* L.) cultivars, an experiment commenced during the winter crop season of 2019–2020 at two locations. The first location was Zmmaar Village, Mosul City, and the second location was in the Sallamiya Region, south of Mosul City, Iraq. The experiments had a randomized complete block design (RCBD) layout with factorial arrangement and three replications. Each experiment included three levels of humic acid (HA1: 0, HA2: 4, and HA3: 8 mg L^{-1}) with three plant densities (PD1: 46,296, PD2: 69,444, and PD3: 138,888 plants ha^{-1}) and three safflower cultivars (C1: Goldasht, C2: Oleic Leed, and C3: Aswan). The safflower with a humic acid concentration of 8 mg L^{-1} resulted in a significant increase in growth, yield, and quality traits compared with the lowest concentration (4 mg L^{-1}) and the control treatment in both locations. Plant density (46296 plants ha^{-1}) was superior by giving the highest seed yield per plant, biological yield, harvest index, oleic and linoleic acid, and oil and protein percentages for both locations. The safflower cultivar Aswan achieved the highest rate of growth, productivity, and quality traits compared with cultivars Oleic Leed and Goldasht at both locations.

Keywords: Safflower (*C. tinctorius* L.) cultivars, humic acid, plant density, seed yield, biological yield, harvest index, oleic and linoleic acid, oil and protein percentage

Key findings: The safflower (*C. tinctorius* L.) cultivars with humic acid foliar application (8 ml L^{-1}) resulted in a significant increase in growth, yield, and quality traits compared with the lowest concentration (4 ml L^{-1}) and the control treatment in both locations.

Communicating Editor: Dr. A.N. Farhood

Manuscript received: August 02, 2023; Accepted: May 14, 2025.

Citation: Al-Doori SAMA (2025). Humic acid and plant density effect on growth, yield components, and quality of safflower (*Carthamus tinctorius* L.). *SABRAO J. Breed. Genet.* 57(6): 2701-2712. http://doi.org/10.54910/sabrao2025.57.6.43.

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is one of the important annual herbaceous crops with multiple uses. Its cultivation is excellent in conditions of rainfed areas. Recently, the use of vegetable oil has increased in cooking, in the manufacture of vegetable butter, mayonnaise, salads, refreshments, sweets, pastries, and jams, and in meat preservation, in addition to its use with spices in most countries (Esendal *et al*., 2008; Ebadia *et al*., 2014). Safflower seeds are the most widely used compared with rapeseed, soybean, sunflower, cottonseed, corn, and palm oil (Weiss, 2002; Ogut *et al*., 2012). It also serves as an animal feed, as the residue left after oil extraction is a good food source for livestock, as it contains up to 25% crude protein.

Furthermore, safflower seeds are effective feeds for birds. Its yellow, orange, or red flowers have direct uses to color cotton, wool, and other hydrophilic fibers with the dye carthamine (Badiger *et al*., 2009). Safflowers are also ingredients to manufacture medicines and cosmetics, with their leaves used in Chinese medicine as a diuretic and treatment of urinary tract infections (Ilkdogan, 2012; Eryılmaz *et al.*, 2014; Rashmi *et al*., 2015). Productivity of safflower incurs effects from genotypes, environmental conditions, and agricultural processes. Safflower tolerates dry conditions, high heat, low cold, and soil salinity. With its deep roots in soil that reach a depth of 2–3 m, roots of plants can absorb moisture and nutrients that are difficult to reach by most crops. This contributes to the improvement of soil texture, which facilitates absorption of organic matter from the soil (Ergonul and Ozbek, 2018, and Zemour *et al*., 2019). The number of fruiting branches produced by the plant ranges from 12 to 16 branches and 10 to 15 seeds per head. The percentage of oil in seeds ranges from 20% to 25%, and protein ranges from 8% to 12%.

Oil contains a high percentage of unsaturated fatty acids, such as oleic and linoleic acids, and saturated fatty acids, and a group of phenolic compounds and flavonoids known as antioxidants (Al-Doori, 2017). These compounds prevent or delay oxidation of fats in cell membranes (Emongor and Oagile, 2017; Ergonu and Ozbek, 2018; Mohammadi *et al*., 2019; Chavoushi *et al*., 2020). Over the past years, many attempts have ensued to increase seed yield in agricultural areas using organic fertilizers. However, setting aside such attempts took a long time, since adding organic fertilizers to soils deficient in their nutrient content continued. Yet, these fertilizers are ineffective due to their slow decomposition, high calcium carbonate content, and some chemical and physical properties of the soil. Hence, foliar spraying with humic acid is one of the most crucial complementary agricultural processes alternative to ground fertilization. It meets the nutritional needs of the plant and improves plant photosynthesis and drought resistance by increasing the rate of gas exchange and the flow of electron transport.

Humic acid contains plenty of nutrients that increase plant growth and productivity regardless of physical or chemical barriers in the soil. The effect of humic acid foliar spray is faster in increasing dry matter accumulation in plants than with ground fertilization, which increases the seed filling period (Malan, 2015; Keshavarz *et al*., 2016; Dotto and Neumann Silva, 2017; Khademian *et al*., 2019; Shaki *et al*., 2020). Plant density is one of the important agricultural factors affecting the growth and productivity of safflower, where changing the distance between plants leads to a change in plant density per unit area. Consequently, it increases the intensity of competition for water and nutrients and reduces the degree of light interception for each plant, as well as the spread of the safflower's root system coverage in the soil (Weiss, 2002; Al-Doori, 2022).

The introduction of newly cultivated varieties can expand the genetic diversity of this crop in developing countries, including Iraq. The selection of new cultivars involves evaluating local varieties, considered key to the first step to break the barrier of low production of oil crops in Iraq. Al-Doori's (2017) results revealed the newly introduced safflower cultivars contributed more in boosting yield per unit area than previously cultivated cultivars. This research took place to

find out the effect of foliar spraying with different concentrations of humic acid and plant density on the growth, yield components, and quality of some safflower cultivars (*Carthamus tinctorius* L.) under two types of soils in Northern Iraq.

MATERIALS AND METHODS

A field experiment, carried out during November of each year in 2019 and 2020, occurred in two locations. The first was in Zmmaar Village, about 80 km west of Mosul City, and the second was in Sallamiya Village, which is about 50 km south of Mosul City. Experiments included 27 factorial treatments that represented combinations among three factors; the first was three concentrations of humic acid (18% produced by the German technology company for products based on humic substances) added at once as a spray on plant leaves at the stage of six leaves formation with a concentration of 0 and 4.8 mg L^{-1}); the second was three plant densities by fixing the distance between lines at 60 cm and changing them between plants (0.36, 0.24, and 0.12 cm) to give plant densities of 46,296, 69,444, and 138,888 plants ha^{-1}), respectively; and three safflower cultivars (Goldasht, Oleic Leed, and Aswan) tested before planting to determine their percentages of germination, which amounted to 95%, 93%, and 97%, respectively.

Each experiment proceeded using a factorial experiment according to randomized complete block design (RCBD) with three replications and factor levels entailing random distribution among experimental units. The analysis of soils of two experimental sites ensued for their chemical and physical properties. The procedure included taking random soil samples at a depth of 30 cm from two experimental sites before planting, according to the method of Page *et al*. (1982), Klute (1986), and Tandon (1999), as shown in Table 1. The field land sustained preparations for cultivation by using a triple-disc plow with orthogonal plowing before the field division process continued, followed by smoothing and leveling processes. Manual sowing of safflower seeds placed three seeds in each hole at a depth of 2 cm on the first and third of November. Meanwhile, harvesting transpired on the 25th and 28th of June for both locations of Zmmaar and Sallamiya, respectively.

Table 1. Some physical and chemical properties of two research sites, Zmmaar and Sallamiya.

Locations		Zmmaar	Sallamiya
Physical traits			
Sand		662.00	800.00
Silt	(gm Kg^{-1})	235.00	120.00
Clay		103.00	080.00
Texture		Sandy loam	Sandy
Chemical traits			
pH		7.40	7.80
Electrical conductivity (ds m^{-1})		2.60	2.20
Cation exchange capacity (cmo.kg^{-1})		12.80	12.00
Available N		4.80	3.60
Available P	(mg kg^{-1})	3.60	3.80
Available K		90.00	60.00
Organic matter	(g kg^{-1})	6.24	4.60
Total $CaCo_3$		16.20	18.00
Dissolved positive and negative ions (1:1)			
Sodium		1.2	1.8
Carbonate		Nil	Nil
Bicarbonate	m.mol.L^{-1}	2.00	2.40
Sulfites		7.2	5.8
Chlorides		2.8	3.2

The experimental unit area was 21.6 m^2, consisting of six lines, with the length of one line at six meters, and the distance was 1.5 meters between one experimental unit and another and between one replicate and another. Cotyledon leaves of plants appeared after one week of cultivation, conducting the grafting process after two weeks due to birds attacking the seedlings, causing some loss. The thinning of plants succeeded after two weeks of planting by leaving one plant in each hole (0.36, 0.24, and 0.12 cm between plants and 60 cm between lines). The experimental soil received nitrogen fertilization as urea (46% N) at 100 kg ha^{-1} added in two batches. The first batch was at planting, and the second was one month after planting. The phosphate fertilizer added had a rate of 200 kg ha^{-1} as the triple calcium superphosphate (48% P_2O_5) during the process of preparing land for cultivation. Potassium fertilizer's one-time addition had the rate of 160 kg ha^{-1} as potassium sulfate (48% K_2O) during planting. The control of insects proceeded when plants reached a height of 10 cm using Diazinon (EC 60%) at 5 cm^3 L^{-1} of water sprayed on plants and Fenvalerate (EC 10%) at 2000 ml ha^{-1}) by adding it to soil before watering. Repeating the application of the second control was 15 days after the first control's treatment. Some weeds appeared in both locations, applying control manually.

After plants reached the final flowering stage for each cultivar, 10 plants, randomly selected from midlines from each treatment, had their following traits measured:

Plant height (cm)—measured from the soil surface to the base of the flowering head; The number of primary branches; Head diameter (cm)—measured using a Vernier micrometer for the part containing disc flowers (Knowles, 1978); The number of seeds per $head^{-1}$—calculated for 10 tablets from each treatment; The weight of a thousand seeds (gm)—computed randomly for 10 tablets from each treatment; Seed yield per plant (gm)—calculated after dropping flower discs of 10 plants, separating their seeds, and weighing them; Biological yield (gm $plant^{-1}$); Harvest index (%)—calculated by the seed yield (gm $plant^{-1}$) divided by the biological yield (gm $plant^{-1}$); and The total seed yield (t ha^{-1}) estimation after dropping flower discs of all plants in the experimental unit, including the sample of 10 plants.

Chemical components in seeds entailed estimation after drying samples in an electric oven at a temperature of 65 °C–70 °C) for two days, then grinding the samples before placing them in bags.

The moisture content adjustment in seeds had a 9% basis. The following components comprised estimations: unsaturated acids (oleic and linoleic) and saturated fatty acids (arachidic, palmitic, and stearic) in oil—taking 0.3 g of ground seeds and esterifying oil by adding 1 ml of the reagent consisting of 25 ml of methanol added to 0.1 ml of acetyl chloride, according to the method of the International Union of Applied Pure Chemistry (IUPAC), as reported by Egan *et al*. (1981). The models succeeded in placing in a GLC device equipped with an electronic computer, with the percentages of unsaturated and saturated fatty acids measured using a computer after diagnosing them based on unsaturated and saturated fatty acids injected into device under same conditions (AL-Kaisey and Hussain, 1995); Oil (%)—the estimation of percentages of oil in seeds used the Soxhlet device according to the Association of Official Analytical Chemists method (A.O.A.C., 1980), including the amount of oil yield; Crude protein (%)—nitrogen in seeds incurred estimation by ammonia distillation using the Micro Kjeldahl apparatus, from which the approximation of the percentage of crude protein relied on the approach of Agrawal *et al*. (1980).

Data of statistically studied traits underwent analysis according to factorial experiment with RCBD separately for each experiment according to Steel and Torrie (1980). Duncan's multiple range test helped compare the means for each source of significant variance (Duncan, 1955).

RESULTS AND DISCUSSION

Effect of humic acid foliar application

Chemical and physical traits of soil play an important role in its effect on the percentage of organic matter and other nutrients. A decrease in organic matter and a high degree of interaction resulting from an increase in calcium carbonate lessen the readiness of most nutrients. Likewise, their unavailability to plants in sufficient quantities and the fact that soil content in both locations for organic matter does not meet the safflower crop's needs. The reason is due to a rise in soil content of calcium carbonate and a high degree of its interaction, causing an elevation in the adsorption of nutrients, with the plant not benefiting from them (Table 1). Spraying humic acid on leaves of plants at concentrations of 4 and 8 mg L^{-1}) reduced the amount of fertilizers added to the soil, decreasing cost and chemical pollution from fertilizers and improving the growth of safflower plants.

Data included the analysis of variance tables indicating that spraying safflower plants with humic acid significantly affected all growth, yield, and quality traits in Zmmaar and Sallamiya locations (Tables 5, 6, and 7). Foliar spraying with humic acid at a concentration of 8 mg L^{-1} (HA3) resulted in a substantial increase in all growth, yield, and quality traits compared with no spraying and the application of less than the HA3 (Tables 2, 3, and 4). The treatment of humic acid spraying on plant leaves at a concentration of 8 mg L^{-1} was superior by giving the highest percentage for the following traits in the Zmmaar and Sallamiya locations, respectively: plant height (31.98% and 33.90%); the number of primary branches (33.77% and 32.27%); the head diameter (88.34% and 97.46%); the number of seeds per $head^{-1}$ (45.18% and 47.26%); the weight of a thousand seeds (26.54% and 25.66%); seed yield per plant (33.50% and 31.33%); biological yield (7.11% and 6.86%); harvest index (20.66% and 20.44%); and the total seed yield (70.29% and 79.56%). Likewise, the same concentration provided the maximum percentages for oleic acid (23.18% and 22.94%), linoleic acid (66.42% and 65.91%), arachidic acid (0.81% and 0.83%), palmitic acid (8.53% and 9.55%), stearic acid (9.64% and 10.76%), oil (26.07% and 26.70%), protein (14.64% and 16.37%), oil yield (150.00% and 157.14%), and protein yield (257.14% and 243.75%) in both locations of Zmmaar and Sallamiya, respectively.

The superiority of safflower plants in all traits of growth, yield, and quality when sprayed with the humic acid to the leaves at a concentration of 8 mg L^{-1} could refer to the importance of the acid in plant growth. It specifically increases permeability of cellular membranes, stimulates enzymatic reactions, and raises cellular divisions, elongating cells. Moreover, it has an essential role in increasing the readiness and absorption of elements (N, P, and K) and (Mn, Zn, and Fe), which enhance plant growth and create the best conditions for cell division, causing an increase in plant enzymes and vitamins' production inside the cells (Al-Doori, 2017). This finding is consistent with what Al-Nafei and Al-Mohammad (2021), Beyyavas (2021), and Heydari *et al*. (2021) obtained.

Effect of plant density

The productivity of the safflower crop has a link to the amount of light falling on plants needed to complete the photosynthesis process, as determined by the vegetation cover or the number of plants per unit area. It is clear from the analysis of variance (Tables 5 to 7) that plant density significantly affected the growth and yield traits of both locations, Zmmaar and Sallamiya. Results presented in Tables 2-4 show that all growth, yield, and quality traits sustained notable influences from plant density. The highest plant height surfaced at a plant density of 138,888 plants ha^{-1}, with an increase of 11.60% and 11.40% compared with the plant density of 46,296 plants ha^{-1} for the Zmmaar and Sallamiya locations, respectively. Perhaps the reason for

Table 2. Effect of mean values of plant height (cm), number of primary branches, head diameter (cm), number of seeds head^{-1}, weight of thousand seed, and seed yield per plant (gm) as affected by concentrations of foliar spraying with humic acid, levels of plant density, safflower cultivars, and their interactions at Zmmaar and Sallamiya locations.

Main effect and interaction	Plant height (cm)		No. of primary branches plant^{-1}		Head diameter (cm)		No. of seeds head^{-1}		1000 seed weight (gm)		Seed yield (gm plant^{-1})	
	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya
Concentrations of humic acid (mg L^{-1})												
H.A1:0	c101.407	c98.2222	c17.4167	c17.2633	c2.23889	c1.9710	c15.8067	c15.740	c31.9441	c32.530	c23.7604	c23.740
H.A2:4	b114.080	b111.968	b19.7859	b19.5266	b2.93481	b2.7470	b18.9119	b18.950	b36.5630	b37.120	b27.0474	b26.950
H.A3:8	a133.834	a131.527	a23.2930	a22.8300	a4.20259	a3.8930	a22.9478	a23.180	a40.4200	a40.880	a31.7215	a31.180
Plant density (plant ha^{-1})												
P.D1:46.296	c109.935	c107.638	a21.3341	a21.0177	a3.47000	a3.2070	a20.6015	a20.550	a37.9396	a38.39	a28.7830	a28.55
P.D2: 69.444	b116.680	b114.170	b20.1830	b19.8944	b3.0822	b2.8490	b19.2210	b19.230	b36.0950	b36.78	b27.320	b27.23
P.D3:138.888	a122.698	a119.909	c18.9781	c18.7077	c2.82407	c2.5560	c17.8433	c18.090	c34.8919	c35.37	c26.4174	c26.09
Safflower cultivars												
C1:Goldasht	c96.8541	c93.6688	c18.3022	c17.9711	c2.82444	c2.6170	c17.5930	c17.580	c34.3811	c34.710	c25.9378	c25.580
C2:OleicLeed	b120.959	b118.663	b20.5011	b20.3455	b3.08704	b2.8280	b19.0959	b19.100	b36.1778	b36.580	b27.4152	b27.100
C3: Aswan	a131.508	a129.385	a21.6922	a21.3033	a3.46481	a3.1670	a20.9774	a21.200	a38.3681	a39.250	a29.1763	a29.200
Interactions effect												
H × P	**	NS	**	NS	**	NS	*	NS	*	NS	**	NS
H × C	**	NS	NS	NS	NS	NS	*	NS	**	NS	*	NS
P × C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
H × P × C	**	NS	*	NS	NS	NS	**	NS	NS	NS	**	NS

Mean followed by different letters within same column differ from each other at levels of 0.05 and 0.01.
*, ** significant at the 0.05 and 0.01 probability level, respectively. N.S. not significant.

Table 3. Effect of mean values of biological yield (gm plant^{-1}), harvest index (%), total seed yield (t ha^{-1}), oleic acid (%), linoleic acid (%), and arachidic acid (%) as affected by concentrations of foliar spraying with humic acid, levels of plant density, safflower cultivars, and their interactions at Zmmaar and Sallamiya locations.

Main effect and interaction	Biological yield (gm plant^{-1})		Harvest index (%)		Total seed yield (t ha^{-1})		Oleic acid (%)		Linoleic acid (%)		Arachidic acid (%)	
	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya
Concentrations of humic acid (mg L^{-1})												
H.A1:0	c143.217	c142.640	c16.5756	c16.6281	c2.02660	c1.86178	c15.5762	c14.970	c53.3956	c52.6933	c0.26741	c0.28074
H.A2:4	b150.366	b148.811	b17.9770	b18.1037	b2.18493	b2.18296	b18.9919	b18.260	b61.3778	b60.3111	b0.47074	b0.48815
H.A3:8	a153.403	a152.434	a20.6633	a20.4425	a3.44385	a3.34822	a23.1852	a22.940	a66.4281	a65.9155	a0.81185	a0.83889
Plant density (plant ha^{-1})												
P.D1:46.296	a150.166	a149.020	a19.1059	a19.1085	c2.26590	c2.21948	a20.4578	a20.090	a62.7881	a61.7622	a0.59000	a0.61074
P.D2: 69.444	b148.960	b148.038	b18.2920	b18.3477	b2.52000	b2.44989	b19.1548	b18.550	b60.5981	b59.6722	b0.51815	b0.53778
P.D3:138.888	c147.856	c146.826	c17.8174	c17.7181	a2.86948	a2.72359	c18.1406	c17.530	c57.8152	c57.4855	c0.44185	c0.45926

Table 3. (cont'd).

Main effect and interaction	Biological yield (gm plant^{-1})		Harvest index (%)		Total seed yield (t ha^{-1})		Oleic acid (%)		Linoleic acid (%)		Arachidic acid (%)	
	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya
Safflower cultivars												
C1:Goldasht	c146.694	c145.442	c17.6256	c17.5377	c2.18952	c2.08433	c18.0140	c17.420	c57.1837	c55.8133	c0.37963	c0.39556
C2:OleicLeed	b149.052	b147.941	b18.3441	b18.2762	b2.41715	b2.35130	b19.0293	b18.380	b60.0937	b59.3988	b0.48556	b0.50296
C3: Aswan	a151.241	a150.502	a19.2463	a19.3603	a3.04871	a2.95733	a20.7100	a20.370	a63.9241	a63.7077	a0.68481	a0.70926
Interactions effect												
H × P	NS	NS	*	NS	NS	NS	NS	NS	*	NS	**	NS
H × C	NS	NS	*	NS	**	NS	NS	NS	**	NS	**	NS
P × C	*	NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS
H × P × C	NS	NS	**	NS	NS	NS	NS	NS	*	NS	NS	NS

Mean followed by different letters within same column differ from each other at levels of 0.05 and 0.01.
*, ** significant at the 0.05 and 0.01 probability level, respectively. N.S. not significant.

Table 4. Effect of mean values of palmitic acid (%), stearic acid (%), oil (%), protein (%), oil yield (t ha^{-1}), and protein yield (t ha^{-1}) as affected by concentrations of foliar spraying with humic acid, levels of plant density, safflower cultivars, and their interactions at Zmmaar and Sallamiya locations.

Main effect and interaction	Palmitic acid (%)		Stearic acid (%)		Oil (%)		Protein (%)		Oil yield (t ha^{-1})		Protein yield (t ha^{-1})	
	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya
Concentrations of humic acid (mg L^{-1})												
H.A1:0	c4.0985	c4.600	c3.5144	c3.8500	c17.9252	c18.6659	c6.9070	c8.6841	c0.36425	c0.35178	c0.14158	c0.16070
H.A2:4	b5.8459	b6.632	b6.1585	b6.9300	b22.4537	b23.3022	b10.6258	b12.2770	b0.49315	b0.51129	b0.23289	b0.26884
H.A3:8	a8.5344	a9.553	a9.6459	a10.760	a26.0767	a26.7063	a14.6437	a16.3719	a0.90235	a0.90244	a0.50915	a0.55142
Plant density (plant ha^{-1})												
P.D1:46.296	a6.8852	a7.852	a7.4515	a8.212	a23.0896	a23.9115	a11.9911	a13.5952	c0.54547	c0.55489	a0.29524	a0.33400
P.D2: 69.444	b6.1185	b6.890	b6.4552	b7.243	b22.0556	b22.8737	b10.5885	b12.3544	b0.57795	b0.58642	a0.28954	a0.32483
P.D3:138.888	c5.4752	c6.043	c5.4122	c6.083	b21.3104	c21.8893	c9.59690	c11.3833	a0.63632	a0.62418	a0.29885	a0.32211
Safflower cultivars												
C1:Goldasht	c4.3000	c4.749	c4.7263	c5.146	c20.0567	c20.9437	c9.0324	c10.8278	c0.45044	c0.45086	c0.21100	c0.23717
C2:OleicLeed	b6.5870	b7.494	b6.6600	b7.553	b22.0152	b22.8580	b10.7156	b12.4480	b0.54525	b0.55580	b0.27295	b0.30650
C3: Aswan	a7.5919	a8.542	a7.9326	a8.840	a24.3837	a24.8722	a12.4285	a14.0570	a0.76405	a0.75875	a0.39967	a0.43719
Interactions effect												
H × P	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
H × C	NS	NS	*	NS	NS	NS	*	NS	**	NS	**	NS
P × C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
H × P × C	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS

Mean followed by different letters within same column differ from each other at levels of 0.05 and 0.01.
*, ** significant at the 0.05 and 0.01 probability level, respectively. N.S. not significant.

Table 5. Analysis of variance for traits: plant height (cm), number of primary branches, head diameter (cm), number of seeds head^{-1}, weight of thousand seed, and seed yield per plant (gm) at Zmmaar and Sallamiya locations.

S.O.V.	d.f.	Plant height (cm)		No. of primary branches plant^{-1}		Head diameter (cm)		No. of seeds head^{-1}		1000 seed weight (gm)		Seed yield (gm plant^{-1})	
		Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya
Block	2	143.14086	114138.86	3.2513778	1373.8936	1.4702419	1.0326974	1.8069679	77.489327	78.281512	7098.4429	28.925486	11336.791
H	2	7210.55**	37158.3**	235.996**	928.747**	26.7646**	18.6821**	346.168**	788.911**	486.234**	1310.87**	432.138**	1356.1**
P	2	1100.77**	3585.3*	37.4717**	30.9339*	2.85404**	0.055640*	51.3498**	41.3153*	63.6230**	52.785*	38.4344**	85.9260*
C	2	8519.64**	12538.0**	79.8568**	331.199**	2.79785**	7.38301**	77.6400**	249.243**	107.649**	646.60**	70.9751**	191.591**
H*P	4	29.147**	100.40NS	0.99145**	13.882NS	0.21344**	0.0610NS	1.221342*	2.4485NS	0.901832*	2.223NS	2.23608**	3.279NS
H*C	4	186.166**	250.40NS	0.4189NS	7.0520NS	0.0187NS	0.0369NS	1.24306**	1.316NS	7.10178**	0.319NS	1.26412**	0.455NS
P*C	4	16.065NS	17.98NS	0.1570NS	0.9748NS	0.0091NS	0.0159NS	0.1568NS	0.9680NS	0.6855NS	0.934NS	0.6511NS	1.571NS
H*P*C	8	18.0910**	18.57NS	0.498410*	5.2951NS	0.0516NS	0.0750NS	1.40508**	0.9411NS	0.4225NS	0.230NS	1.64744**	0.809NS
Error	52	5.41907	379.5322	0.2118393	14.139557	0.0456548	0.2654650	0.4549653	9.224378	0.370889	25.52456	0.445197	17.81641
Total	80												

Table 6. Analysis of variance for traits: biological yield (gm plant^{-1}), harvest index (%), total seed yield (t ha^{-1}), oleic acid (%), linoleic acid (%), and arachidic acid (%) at Zmmaar and Sallamiya locations.

S.O.V.	d.f.	Biological yield (gm plant^{-1})		Harvest index (%)		Total seed yield (t ha^{-1})		Oleic acid (%)		Linoleic acid (%)		Arachidic acid (%)	
		Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya
Block	2	63.442193	39.098414	7.9342975	16.924446	0.2157770	1.3439840	16.171669	10.769127	99.979753	305.74256	0.7935814	0.53.6695
H	2	738.330**	211.801**	116.506**	921.73**	16.2834**	26.4991**	392.164**	122.250**	1165.81**	2128.15**	2.04354**	2.912**
P	2	36.0498**	18.21519*	11.4641**	74.991**	2.47956**	3.68541**	36.4295**	61.7927**	167.721**	88.73370*	0.14819**	1.707665*
C	2	139.646**	754.380**	17.8068**	24.540**	5.35009**	5.4043**	50.0594**	23.9028**	308.575**	176.013**	0.64828**	0.38347**
H*P	4	0.9144NS	0.96.90NS	0.812853*	0.6937NS	0.0366NS	0.3302NS	0.5719NS	2.9020NS	4.089020*	1.5073NS	0.01863**	0.418NS
H*C	4	0.5581NS	2.3861NS	0.81995**	1.490NS	0.18158**	0.1347NS	0.4734NS	1.6920NS	4.79506**	3.6060NS	0.06074**	0.2137NS
P*C	4	1.824700*	3.1800NS	0.3332NS	0.321NS	0.10690*	0.0360NS	0.0421NS	0.5047NS	1.7104NS	1.6098NS	0.0075NS	0.0862NS
H*P*C	8	0.4869NS	2.9844NS	0.68196**	0.655NS	0.0528NS	0.020NS	0.3035NS	0.3285NS	3.019300*	1.7220NS	0.0048NS	0.0490NS
Error	52	0.711321	0.572.305	14.56409	16.096695	0.335556	0.2954528	37.7673	12.570811	0.2461680	0.1949043	0.0047943	0.4419709
Total	80												

Table 7. Analysis of variance for traits: palmitic acid (%), stearic acid (%), oil (%), protein (%), oil yield (t ha^{-1}), and protein yield (t ha^{-1}) at Zmmaar and Sallamiya locations.

S.O.V.	d.f.	Palmitic acid (%)		Stearic acid (%)		Oil (%)		Protein (%)		Oil yield (t ha^{-1})		Protein yield (t ha^{-1})	
		Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya	Zmmaar	Sallamiya
Block	2	21.876400	26.888055	25.167600	190.25707	438.97410	764.86829	20.302149	32.411119	0.2244872	0.3762228	0.0087399	0.3672754
H	2	134.815**	210.671**	255.366**	656.595**	450.359**	1385.53**	404.229**	142.543**	2.13129**	5.19112**	0.98894**	8.4361**
P	2	13.4539**	6.8099**	28.0753**	19.987**	21.5566**	63.6479*	39.0730**	98.75730*	0.05722**	0.577731*	0.00059**	0.6170**
C	2	76.8441**	182.835**	70.3756**	25.0331**	126.760**	224.192**	77.8519**	168.164**	0.69843**	3.88915**	0.24969**	0.8970**
H*P	4	0.4602NS	2.8319NS	0.6034NS	0.6472NS	0.7536NS	2.592NS	0.7778NS	3.1816NS	0.0020NS	0.9698NS	0.0012NS	0.088NS
H*C	4	1.2492NS	0.1639NS	1.853368*	0.5157NS	1.1675NS	3.394NS	1.100250*	1.7768NS	0.0573NS	0.0864NS	0.0290NS	0.0300NS
P*C	4	0.2580NS	0.1684NS	0.2367NS	0.0630NS	1.2895NS	1.393NS	0.2453NS	0.2795NS	0.0127NS	0.0367NS	0.0099NS	0.0500NS
H*P*C	8	0.3112NS	0.352NS	0.3533NS	0.170NS	1.1175NS	1.45NS	0.5634NS	0.4319NS	0.0015NS	0.0419NS	0.001422*	0.012NS
Error	52	0.5206051	0.1457951	0.6343205	3.7728470	3.231141	21.56882	0.352963	12.92975	0.0062685	0.7480747	0.0006873	0.3391830
Total	80												

the plant height's increase in high plant densities is due to a misleading escalation, which allows auxin to work in cooperation with gibberellins to elongate internodes, resulting in a plant height boost. These results were consistent with the findings of AL-Doori (2017), who stated that an increase in plant density caused an enhancement in plant height, which led to a competition between plants at high densities for light and different production factors. Consequently, it led to misleading among plants, and this pushed them toward a higher height.

The number of primary branches behaved opposite to the behavior of plant height in terms of being affected by the plant density, as the highest number of primary branches of safflower plants occurred at the plant density of 46,296 plants ha^{-1}. It was significantly superior to other densities when compared to the plant density of 138,888 plants ha^{-1}, which gave a percentage of increase in the number of primary branches of 12.44% and 12.35% for Zmmaar and Sallamiya locations, respectively. The superiority of the number of primary branches of safflower plants at low plant densities may be due to a few plants per unit area. As a result, it led to a lack of competition between plants for different growth elements and light. The head diameter performed similarly to the behavior of the number of primary branches as affected by plant density. The head diameter decreased with an increase in plant density, with the lowest diameter of flowering head achieved at a plant density of 138,888 plants ha^{-1}. It showed a decrease of 23.04% and 25.49% compared with the plant density of 46,296 plants ha^{-1} for both locations, Zmmaar and Sallamiya, respectively.

Plant density remarkably influenced the number of seeds per head, which increased with a decrease in plant density. The most seeds per head was evident at a plant density of 46,296 plants ha^{-1}, with an increase of 15.47% and 13.59% compared with the plant density of 138,888 plants ha^{-1} for two locations, Zmmaar and Sallamiya, respectively. The weight of a thousand seeds gradually rose when reducing the plant density, reaching its highest limit at 46,296 plants ha^{-1} in the Zmmaar location, with an increase of 8.71%, and in the Sallamiya location (8.53%).

Plant density also excelled for 46,296 plants ha^{-1} by giving the maximum amount of individual plant seed yield (8.97% and 9.42%), biological yield (1.56% and 1.49%), and harvest index (19.10% and 19.10%) for the two locations of Zmmaar and Sallamiya, respectively. The decrease of most yield traits of safflower plants with an increase in plant density may be due to a rise in competition for various production elements, especially moisture and nutrients, as well as a boost in competition for light. This led to an increase in plant height at the expense of the rest of the traits. The total seed yield represents the final component of yield, which includes the number of primary branches, head diameter, the number of seeds per head, and the weight of a seed. As a result, the highest yield of seeds arises when growth factors are suitable for a cultivar superior in these four components. When comparing the individual plant yield with the total seed yield, we find they are in opposite directions, as individual plant yield decreases with increasing plant density, while total seed yield increases. This may refer to an escalation in the number of plants per unit area, and as a result, total seed yield is higher than the individual plant yield, reaching optimum plant density (46,296 plants ha^{-1}). Any increase over this amount leads to a decrease in total seed yield, and this is clear in the research results.

The plant density of 46,296 plants ha^{-1} was significantly superior in the total seed yield over other densities, when seed yield reached 2.86 and 2.72 t ha^{-1}, with an increase of 26.54% and 23.07% for two locations, Zmmaar and Sallamiya, respectively (Tables 2 and 3). Increasing plant density from 46,296 to 138,888 plants ha^{-1} significantly affected all qualitative traits, except protein yield in both locations (Tables 3 and 4). The percentages of oleic acid (20.45% and 20.09%), linoleic acid (62.78% and 61.76%), arachidic acid (0.59% and 0.61%), palmitic acid (6.88% and 7.85%), stearic acid (7.45% and 8.21%), oil (23.08% and 23.91%), and protein (11.99% and 13.59%) decreased with an increasing plant density from 46,296 to 138,888 plants ha^{-1} in

both locations, Zmmaar and Sallamiya, respectively. Meanwhile, oil yield behaved opposite to other qualitative traits when increasing plant density. This is mainly due to a boost in the total seed yield by raising the plant density and not from an increase in the percentage of oil, as oil yield increased by 16.66% when increasing density reached 138,888 plants ha^{-1}) at the Zmmaar location, with a rate of 12.72% at the Sallamiya location (Tables 3 and 4). These results aligned with results mentioned by Al-Doori (2017) and Moatshe *et al*. (2020).

Cultivars' effect

Cultivars differed considerably for the growth, yield, and varietal traits in both Zmmaar and Sallamiya locations (Tables 5-7). The data presented in Table 2 indicate the height of the safflower plant stem incurred significant effects from different cultivars. Plants of the Aswan cultivar recorded the tallest height for plant stem, with an increase rate of 35.77% and 38.13% for two locations, Zmmaar and Sallamiya, respectively. The increasing height of the safflower plants' stem could be vital in enhancing the height of vascular bundles and containers carrying nutrients and nutritional compounds. This leads to benefiting from those absorbed nutrients by the root, on the one hand. Meanwhile, a rising height of the safflower stem may lead to an increase in the amount of dry matter in the vegetative part of plants. Consequently, it diverts part of the plant's effort to build the dry matter in the vegetative area instead of contributing to building components of the seed, resulting in a reduced harvest index. Moreover, increasing the height of the plant stem may cause some problems when harvesting this crop. Addressing these concerns can come from using the appropriate plant density for each variety to achieve balance and give the best investment for plant morphological, anatomical, and productivity specifications.

The cultivar Aswan achieved the highest ratio for the following traits: the number of primary branches (18.52% and 18.53%); head diameter (22.69% and 21.07%); the number of seeds $head^{-1}$(19.21% and 20.59%); weight of a thousand seeds (11.57% and 13.07%); seed yield per plant (12.49% and 15.39%); biological yield (3.10% and 3.47%); harvest index (19.24% and 19.36%); and total seed yield (39.44% and 41.82%) in Zmmaar and Sallamiya, respectively. Likewise, the said cultivar gave the following maximum percentages: oleic acid (20.71% and 20.37%); linoleic acid (63.92% and 63.70%); arachidic acid (0.68% and 0.70%); palmitic acid (7.59% and 8.54%); stearic acid (7.93% and 8.84%); oil content (24.38% and 24.87%); protein content (12.42% and 14.05%); oil yield (68.88% and 66.66%); and protein yield (85.71% and 86.95%), as compared with OleicLeed and Goldasht cultivars for both locations, Zmmaar and Sallamiya, respectively. The superiority of the Aswan cultivar for growth, yield, and quality traits could refer to the physiological nature and morphological form of this cultivar. Its plants contained a longer stem, larger discs, and more branches, which led to an increased competition for water and nutrients, as reflected in all mentioned traits (Tables 2–4). Results of this research agree with what Al-Doori (2013), Hamza (2014), and Al-Nafei and Al-Mohammad (2021) mentioned.

Interaction effects

Results of the variance analysis (Tables 5–7) refer to the interaction between foliar sprays of humic acid and plant density, which was significant only for these traits: plant height, the number of primary shoots, head diameter, the number of seeds per head, a thousand seed weight, seed yield per plant, indicative harvest, linoleic acid, and arachidic acid at the Zmmaar location. Meanwhile, interaction between foliar spraying of humic acid and cultivars was significant only for these traits: plant height, the number of seeds per head, a thousand seed weight, seed yield per plant, harvest index, total seed yield, linoleic acid, arachidic acid, stearic acid, protein percentage, oil yield, and protein yield at the Zmmaar location. The interaction between plant density and cultivars was substantial only for traits of biological yield and total seed yield in the Zmmaar location only. The interaction among

three research factors (humic acid × plant density × cultivars) was remarkable for the following traits: plant height; the number of primary branches; the number of seeds per plant; seed yield per plant; harvest index; linoleic acid; and protein yield only at the Zmmaar location. For this reason, a discussion on the interactions was not applicable (Table 5–7).

CONCLUSIONS

Results of the presented research showed a considerable positive indicator of possibly cultivating safflower (Aswan cultivar) with a plant density of 46,296 plants ha^{-1} and spraying humic acid on leaves at a concentration of 8 mg L^{-1}. These rates produce the highest amount of total seed yield, unsaturated fatty acids, oil, and protein percentage under conditions of the Nineveh Governorate in both locations of Zmmaar and Sallamiya, with the same degree of success.

REFERENCES

A.O.A.C. (1980). Official methods of analysis, Association of Official Analytical Chemists. Washington, U.S.A.

Agrawal SC, Jolly MS, Sinha AM (1980). Foliar constituents of secondary food plants of tasar silk *Antheraea mylitta*. *Ind. J. For.* 106 (12): 847-851.

Al-Doori SAM (2013). Performance of some safflower genotypes (*Carthamus tinctorius* L.) according to varying row spacing and nitrogen fertilizer levels. *J. Tikrit Univ. Agric. Sci.* 13(3): 15-20.

Al-Doori SAM (2017). Determination of optimum sowing date and plant population of some safflower cultivars (*Carthamus tinctorius* L.) under Mosul city conditions. *Mes. J. Agric.* 45(2): 331-342.

Al-Doori SAM (2022). Effect of phosphorous fertilizer and plant density on morphological traits, yield components and quality of some genotypes (*Sesamum indicum* L.). *Int. J. Agric. Stat. Sci.* 18(1): 1017-1024. https://connectjournals.com/03899.2022.18.1017.

AL-Kaisey MT, Hussain AAK (1995). Chemical composition of soybean seeds. *Dirasat Pure Appl. Sci.* 22: 1193-1200.

Al-Nafei HAK, Al-Mohammad MHS (2021). Effect of planting distance and humic acid on growth, yield and antioxidant activity of safflower petals and seed. Fourth International Conference for Agricultural and Sustainability Sciences. *IOP Conf. Series: Earth and Environ. Sci.* 910: 1-5. doi: 10.1088/1755-1315/910/1/012031.

Badiger PK, Rudranaik V, Parameshwarappa KG, Patil MS (2009). Genotype x environmental interactions and stability analysis of non-spiny breeding lines in safflower. *Karnataka J. Agric. Sci.* 22(5): 978-981.

Beyyavas H (2021). Effects of humic acid and iron applications on the yield, some plant characteristics and oil ratio of safflower (*Carthamus tinctorius* L.). *Appl. Ecol. Environ. Res.* 19(1): 307-319. http://dx.doi.org/10.15666/aeer/1901_307319.

Chavoushi M, Najafi F Salimi, A and Angaji SA (2020). Effect of salicylic acid and sodium nitroprusside on growth parameters, photosynthetic pigments and secondary metabolites of safflower under drought stress. *Scien. Hortic.* 259. https://doi.org/10.1016/j.scienta.2019.108823.

Dotto L, Neumann Silva V (2017). Beet seed priming with growth regulators. *Semina: Ciencia Agrarias* 38: 1785-1798. doi: 10.5433/1679-0359.2017v38n4p1785.

Duncan BO (1955). Multiple range and multiple F test. *Biometrics* 11: 1-42.

Ebadia F, Mohsenia M, Alizadehb AM (2014). Evaluation of antioxidant activity of safflower florets (*Carthamus tinctorius* L.) as food coloring agents. *J. Chem. Pharm. Res.* 6(8): 539-544.

Egan HR, Krik S, Saweyer R (1981). Pearsons' Chemical Analysis of Foods. Churchill Livingstone, New York, USA, pp. 591.

Emongor V, Oagile O (2017). Safflower Production. Published by: The Botswana University of Agriculture and Natural Resources Private Bag 0027 Gaborone, Botswana. ISBN 978-99968-0-607-0.

Ergonul PG, Ozbek ZA (2018). Identification of bioactive compounds and total phenol contents of cold pressed oils from safflower and camelina seeds. *J. Food Meas. Charac*. 12: 2313-2320. https://doi. org/10.1007/s11694-018-9848-7

Eryılmaz T, Yesilyurt MK, Cesur C, Yumak H, Celik SA, Yıldız AK (2014). Determination of fuel properties of biodiesel produced from safflower (*Carthamus tinctorius* L.) Dincer species grown in Yozgat province conditions. *J. Agric. Fac. Gazi. Univ*. 31(1): 63-72. http://www.redalyc.org/articulo.oa?id=46543855007.

Esendal E, Istanbulluoglu A, Arslan B, Pasa C (2008). Effect of water stress on growth components of winter safflower (*Cathamus tinctorius* L.). In: The 7th International Safflower Conference, 3-6 Nov 2008. Safflower: Unexploited Potential and World Adaptability. Australian National Wine and Crape Industry Training Centre Wagga, New South Wales, Australia.

Hamza M (2014). Stability analysis of seed and oil yields in safflower genotypes under divergent environments in Egypt. *Egyp. J. Appl. Sci*. 29 (12B): 743-757.

Heydari M, Hamid R, Tohidi M, Farshad G, Seyed AM, Modarres Sanavy, Pourang K (2021). Foliar application of humic acid and some exo and endophytic growth hormones on yield, yield components and fatty acid composition in safflower (*Carthamus tinctorius* L.) under drought stress. *J. Agric. Sci.* 27(4): 500-508. doi: 10.15832/ ankutbd. 748132.

Ilkdoga U (2012). The necessary conditions for safflower production and the formation of policies in Turkey. Ph.D. Thesis. Institute of Science and Technology, Agricultural Economy Department, Ankara University, Ankara, Turkey.

Keshavarz H, Modarres Sanavy SAM, Sadegh Gol Moghadam R (2016). Impact of foliar application with salicylic acid on biochemical characters of canola plants under cold stress conditions. *Notulae Sci. Biol.* 8(1): 98-105. doi: 10.15835/nsb.8.1.9766.

Khademian R, Ghassemi S, Asghari B (2019). Bio-fertilizer improves physio-biochemical characteristics and grain yield of safflower (*Carthamus tinctorius* L.) under drought stress. *Russ. Agric. Sci.* 45: 458-463.

Klute A (1986). Method of soil analysis. Part (1) 2nd Monograph No. 9. Agronomy.

Knowles PF (1978). Morphology and anatomy. In: Safflower Science and Technology charter. *J. of Agron*. (19) USA Madison, Wisconsin, USA, pp. 505.

Malan C (2015). Humic and fulvic acids. A practical approach. In: Sustainable Soil Management Symposium, Stellenbosch, 5-6 November 2015, Agri. Librium Publisher.

Moatshe OG, Emongor VE, Balole TV, Tshwenyane SO (2020). Safflower genotype by plant density on yield and phenological characteristics. *Afr. Crop. Sci. J.* 28(51): 145-163. https://dx.doi.org/10.4314/acsj.v28i1.11S

Mohammadi MH, Sharifi P, Shorafa M (2019). Comparison of the effect of cow manure, vermicompost, and azolla on safflower growth in a saline-sodic soil. *Commun. Soil Sci. Plant Anal.* 50 (12).

Ogut H, Oguz H, Bacak S, Mengeş HO, Kose A, Eryılmaz T (2012). Investigation of the characteristics of biodiesel from Balci species of safflower. *J. Agric. Mach. Sci.* 8(3): 297-300. oilhttps://doi.org/10.30910/turkjans.1294598

Page AL, Miller RH, Kenney DR (1982). Methods of soil analysis. Part (2) Agronomy No. 9 Madison, USA.

Rashmi D, Ashwini A, Kumar D (2015). A review on potential pharmacological uses of *Carthamus tinctorius* L.). *World J. Pharm. Sci.* 3(8): 1741-1746. http://www.wjpsonline.org

Shaki F, Niknam V, Ebrahimzadeh MH (2020). Effects of penconazole on hormonal crosstalk and fatty acids from salt-stressed safflower. *Iran J. Plan. Phys.* 10(3): 3213-3221. doi:10. 30495/ IJPP. 2020. 1872682.1149

Steel RGD, Torrie JH (1980). Principles and Procedures of Statistics. MCGraw-Hill, New York.

Tandon H (1999). Methods of Analysis of Soil, Plants, Water and Fertilizers. Fertilizer Development and Consultation Organization, New Delhi, India, pp. 144.

Weiss EA (2002). Oilseed Crops Safflower, Second Edition, Blackwell Publishing Limited Science, Oxford, London, UK. Chapter: 4, pp. 93-129.

Zemour K, Amina L, Ahmedbadda AED, Thierry T, Othman M (2019). Phenol content and antioxidant and anti-aging activity of safflower seed oil. (*Carthamus tinctorius* L.). *J. Cosm.* 6:55-62. doi: 10. 3390/ cosmetics6030055