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Impact of Plant Density and Humic Acid Application on Yield, Yield Components and Nutrient Uptakes of Sunflower (*Helianthus annuus* L.) Grown in a Newly Reclaimed Soil

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ABSTRACT

A study was carried out as field experiments at Demo experimental station, Fayoum district in summer seasons 2015 and 2016 to investigate the effects of plant density and humic acid soil application on oil content, nutrient uptakes, vegetative growth and yield of sunflower (*Helianthus annuus* L.) plants. A split plot layout within a randomized completely blocks design with 3 replications were used. Three treatments of plant density i.e., D_1=47,619 plant/ha^{-1} (0.7x0.3 m), D_2=71,428 plant/ha^{-1} (0.7x0.2 m) and D_3= 95,238 plant/ha^{-1} (0.7x0.15 m) were placed in the main plots. The subplot treatments were 5 levels (0.0, 1.25, 2.5, 3.75 and 5 kg ha^{-1}) of humic acid. The results indicated that the plant density D_1 gave the highest values of plant height, number of leaves plant^{-1}, leaf, stem and head dry weights plant^{-1} and seed yield plant^{-1}. However, the plant density D_2 recorded the highest seed yield ha^{-1}. Both plant densities (D_1) and (D_2) surpassed D_3 concerning on values of leaf and seed (N, P, K, Mg, Mn, Zn and Fe) uptakes. Soil addition of humic acid at rate of 5 kg ha^{-1} significantly produced the highest values of growth parameters, yield, its components as well as oil content and nutrient uptakes in both seasons. The highest sunflower seed yield was obtained when plant density was 71.428 plant ha^{-1} (D_2) and treated with 5 kg ha^{-1} of humic acid as a soil application.
Keywords: Sunflower, Plant density, Humic acid.

INTRODUCTION

Seed-oil crops are the second largest grown field crops in the world after cereals (Novák and Máriás, 2013). Sunflower is considered one of the most important oil crops in many countries (Abdou *et al.*, 2011), whereas, it occupies the fourth position among seed-oil crops after soybean, palm and canola (Rodriguez *et al.*, 2002; Petcu *et al.*, 2010 and Bukhsh *et al.*, 2011). It is grown on about 25 million acres worldwide (FAO, 2013). It (*Helianthus annuus* L.) belongs to a group of the most significant annual crops which are grown for oil production. Sunflower seeds that contain oil (36-52%) and protein (28-32%) (Rosa *et al.,* 2009). The oil extracted from sunflower seeds is a good vegetable oil source for cooking manufacture of margarine, paints, soap and other cosmetics (Bamgboye and Adejumo, 2007). In Egypt, sunflower receives considerable attention due to its short growth season. It can also be well grown in a wide range of low fertility soils in newly reclaimed areas.

Plant population density is an important factor affecting growth and yield. In addition, plant spacing is one of the most important production factors. It is often manipulated in order to ensure optimum plant populations to reduce the yield losses due to overcrowdings that influence sunflower yield and seed oil percentage (Basha, 2000 and Allam *et al.*, 2003). Increasing the plant scourge per unit area incrementally increased sunflower plant height and biological yield per unit area (Ali *et al.* (2012b); Ibrahim (2012); Awais *et al.* (2013); Radwan *et al.* (2013; Ali *et al.,* (2014), Baghdadi *et al.*, (2014) and Ravichandran and Srinivasan (2017). On the other hand, increasing the plant score significantly decreased the stem and head diameter, head dry weight and seed yield plant^{-1} (Ibrahim, 2012; Awais *et al.*, 2013 and Radwan *et al.*, 2013). However, Beg *et al.*, (2007) found that plant population had no significant effect on growth parameters of sunflower such as plant height, stem and head diameter. Yield and yield components of sunflower are significantly affected by plant population. Therefore increase in the plant population increases seed oil and protein yields per unit area (Ibrahim, 2012; Awais *et al.*, 2013; Ali *et al.*, 2014; and Hatami 2017). On the contrary, the opposite trend was observed by (Radwan *et al.*, 2013, Baghdadi *et al.*, 2014), and Ravichandran and Srinivasan (2017). Moreover, Al-Thabet (2006), Rauf *et al.* (2012), Awais *et al.*, (2013) and Yasin *et al.*, (2013) mentioned that the plant density showed no significant effect either on oil or protein percentage. Plant populations were reported to influence the nutrient uptake by sunflower. A high nutrient uptake caused by high plant population level was recorded by Ravichandran and Srinivasan (2017)

Humic acid (HA) is formed through the chemical and biological humification of plant and animal organic matter and through the biological activities of microorganisms (Fahramand *et al.*, 2014). Several researchers indicated that HA application as foliar spray enhanced the plant growth, nutrient uptake and yield and improved the quality of some crops. It may decrease the soil application of N, P and K fertilizers applied causing low environment pollution and cost (Neri *et al.*, 2002 and El-Desuki 2004). Humic acid applications improve the yields of some field crops (Ulukan, 2008). Humic acid is considered an integral part of fertilization program and soil fertility (El-Ghamry *et al.* 2009). It has several advantages and benefits. Applying humic substances improved growth, yield, oil and protein percentage, and nutrient uptakes of many crops such as maize (Sharif *et al.,* 2002), wheat (Tahir *et al.*, 2011), *Brassica sp* (Ali *et al.*, 2014), *Panicum miliaceum* L. (Saruhan *et al.,* 2011), chickpea (Saadati and Baghi, 2014), Cucumber (Rauthan and Schnitzer (1981), Bean (Kaya *et al.* 2005) and Tomato (Yildirim, 2007). In contrast, Pavlíková *et al.*, (1997), Cooper *et al.*, (1998) and Defline *et al.,* (2008) indicated that the application of potassium humate or humic acids during the growth season of some crops did not have significant effects on the plant growth and yields of these crops.

The objective of this study is to investigate effects of plant population density and soil application of humic acid on growth, yield, yield components and nutrient uptakes of sunflower grown on newly reclaimed soils.

MATERIALS AND METHODS

Two field experiments were carried out at Demo Research Farm, south east Fayoum (29º 17'N; 30º 53'E), Fayoum University, Egypt, during the two successive summer seasons of 2015 and 2016 to examine the effects of plant density and humic acid application on

yield, yield attributes and nutrient uptakes of sunflower (*Helianthus annuus* L.) grown on sandy clay loam soil. Sunflower seed of Sakha 53 variety, obtained from the Oil Crop Research Section, Field Crop Research Institute, Agricultural Research Center, Giza, Egypt at a rate of 10 kg ha^{-1}were sown on 25th and 27th of May in the first and second seasons, respectively.

In both seasons, the experiments were carried out after wheat to avoid any variations in the residual effect of the preceding crop. The area of the experimental unit was 10.5 m^2 (3.5 m length and 3.0 m width). The trials were laid out in a split-plot design in a randomized complete block arrangement with three replications. Plant population density treatments i.e., D_1=47,619 (0.7x0.3 m), D_2=71,428 (0.7x0.2 m) and D_3= 95,238 plants ha^{-1} (0.7x0.15 m) were assigned to the main plots and humic acid i.e., 0.0, 1.25, 2.5, 3.75 and 5 kg ha^{-1} were assigned in the sub-plots. The Humic acid was added in two equal doses as a soil application with the second and third irrigation.

Soil samples were taken from the surface layer (0-30 cm) of the experimental sites growth season to determine some selected physical and chemical properties of this soil (Table 1). The texture was determined using the hydrometer method (Bouyoucos, 1981). The pH of the soil paste and the electronic conductivity of the soil paste extracted (ECe) was measured according to (Jackson, 1962). Calcium carbonate equivalent (Loppert and Suarez, 1996) and the organic matter content of the soil (Nelson and Sommers, 1996) were also determined. Total soil nitrogen was determined according to the Kjeldahl method (Bremmer1996). Available potassium (K) was extracted by 1 N ammonium acetate and then, measured using the flame photometer (Helmek and Sparks, 1996). Sodium biocarbonate-extractable P was determined by spectrophotometer (Olsen, 1954). Available micronutrients were extracted using the DPTA method (Lindsay and Norvell, 1978) and measured by the inductively coupled plasma mass spectrometry (ICP).

The experimental site was cultivated under conventional tillage. Calcium supper-phosphate (15.5 % P_2O_5) was added before ridging at the rate of 476 Kg ha^{-1}. Nitrogen was applied in two equal doses at the rate of 107 kg ha^{-1} (as ammonium nitrate 33.5% N) with the second and third irrigation. The plants were thinned was after 15 days from planting to secure one plant per hill.

Table 1. Soil physical and chemical properties of the experimental site in both 2015 and 2016 growth seasons.

Properties	2015	2016
Sand %	64.9	65.7
Silt %	8.4	8.9
Clay %	26.7	25.4
Soil texture	Sandy Clay loam	Sandy Clay loam
pH	7.82	7.68
ECe, dSm^{-1}	6.14	8.16
$CaCO_3$ %	7.8	7.6
Organic matter %	1.02	1.06
	Available Nutrients mg kg^{-1}	
Available N	130	145
Available P	11.3	12.5
Available K	340	352
	DTPA-Extractable Micro-nutrients mg kg^{-1}	
Fe	13.5	14.2
Mn	1.84	1.93
Zn	0.09	0.12
Cu	0.05	0.08

At maturity a random composite sample of five guarded plants was taken from the ridges outside the two central ones in each sub-plot. Yield and yield attributes (plant height, head diameter, stem diameter, number of leaves $plant^{-1}$, head dry weight, stem and leaves dry weights and seed yield $plant^{-1}$) were determined in these plant samples. The plants grown on the middle two ridges in each sub-plot were used to determine the seed and biological yields per hechtar. The total uptakes nutrient of N, P, K, Mg, Mn, Zn and Fe were determined by multiplying the nutrient percentage in plant leaves by biological yield ha^{-1} (seed and leaves). The analysis of variance (ANOVA) and LSD were calculated by using GENSTAT statistical package, version 9.2 (GENSTAT, 2007). All other recommended agricultural practices for sunflower production were adopted throughout growth seasons of 2015 and 2016 according to the bulletin of Egyptian Ministry of Agriculture (1020/2006).

RESULTS AND DISCUSSION

1. Growth Parameters

Plant density effect:

The effect of plant density and humic acid application on some sunflower growth parameters is present in Table (2). The plant density had a significant effect on all studied traits in both growth seasons except plant height, stem diameter and head diameter in the second season. The results cleared that plant density D_1 (47,619 plant ha^{-1}) surpassed the other two plant densities D_2 (71,428 plant ha^{-1}) and D_3 (95,238 plant ha^{-1}) in most growth parameters except plant height in both seasons. Averages values of D_1 for stem diameter, head diameter and leaf, stem and head dry weights $plnat^{-1}$ for D_1 in the first season were higher by 12.34, 9.77, 11.68, 12.30 and 6.14 % respectively, than those of D_2 and by 36.08, 29.47, 39.02, 37.56 and 40.46 % respectively, than those of D_3. The same trend was observed in the second season, where the main values of those respectively parameters for D_1 were higher by 6.02, 7.00, 13.70, 22.82 and 14.51% than those of D_2 and by 10.69, 21.01, 38.52, 41.05 and 47.33 % than those of D_3. However, plant density significantly showed the highest values of plant height in both seasons. Plant densities (D_1) and (D_2) which were statistically, significantly surpassed D_3 in number of leaves $plant^{-1}$ in both seasons. These results are supported by those (Ibrahim, 2012; Awais *et al*., 2013; Radwan *et al*., 2013; Ali *et al*., 2014 and Baghdadi *et al*., 2014). On the other hand, increasing plant score significantly decreased stem and head diameters, head dry weight and seed yield $plant^{-1}$ as indicated by (Ibrahim, 2012; Awais *et al*., 2013 and Radwan *et al*., 2013. However, Beg *et al*.,

(2007) found that the plant population had no significant effect on growth parameters such as plant height, stem and head diameter.

Humic acid effect:

The soil application of humic acid significantly affected all growth parameters of sunflower in both seasons (Table 2). The Humic acid applied level at 5.00 kg ha^{-1} caused a significant increases in plant height, stem diameter, number of leaves, head diameter and leaf, stem and head dry weights $plant^{-1}$ in the first season by 17.67, 40.84, 31.52, 37.02, 82.09, 83.29 and 73.23 %, respectively and by 36.99, 52.59, 32.98, 81.54, 63.31, 63.36 and 73.39 %, respectively in the second season compared to the control. These increments may be attributed to the role of humic acid in stimulating amino acid building and growth hormones, which in turn positively promote cell division and enlargement. These results are in the same trend with those obtained by Rajpar *et al.,* (2011) and Ali *et al*., (2014) on canola, Saruhan *et al.,* (2011) on *Panicum miliaceum* L., Tan and Nopamornbodi (1979) and Sharif *et al.,* (2002) on maize, Saadati and Baghi (2014) on chickpea, Rauthan and Schnitzer (1981) on Cucumber, Kaya *et al.,* (2005) on common bean. and Yildirim (2007) on tomato.

Table 2. Main effect of plant density and humic acid on some growth parameters of sunflower grown in 2015 and 2016 seasons.

Treatment	Plant height (cm)	Stem diameter (cm)	No. of leaves $plant^{-1}$	Head diameter (cm)	Leaf dry weight $plant^{-1}$(g)	Stem dry weight $plant^{-1}$ (g)	Head dry weight $plant^{-1}$ (g)
				2015 season			
D_1=47,619 plants ha^{-1}	206.70	2.64	29.03	22.63	29.93	79.81	273.89
D_2=71,428 plants ha^{-1}	216.07	2.35	31.27	20.37	26.80	71.07	257.97
D_3=95,238 plants ha^{-1}	230.07	1.94	28.47	17.27	21.53	58.02	194.99
Plant density (A)	*	**	*	**	*	**	**
$LSD_{0.05(A)}$	14.82	0.29	2.05	0.76	4.29	4.52	19.19
Zero kg ha^{-1}	198.67	1.91	25.89	16.83	17.87	47.53	175.92
1.25 kg ha^{-1}	212.33	2.15	27.83	18.22	22.96	61.61	207.54
2.50 kg ha^{-1}	218.33	2.33	29.06	20.72	26.50	71.48	246.19
3.75 kg ha^{-1}	224.94	2.47	31.11	21.61	30.55	80.42	276.02
5.00 kg ha^{-1}	233.78	2.69	34.05	23.06	32.54	87.12	304.74
Humic acid (B)	**	**	**	**	**	**	**
$LSD_{0.05(B)}$	5.40	0.10	1.18	1.01	2.18	11.08	21.67
				2016 season			
D_1=47,619 plants ha^{-1}	157.13	1.76	26.60	20.33	24.31	67.07	248.88
D_2=71,428 plants ha^{-1}	167.13	1.66	25.00	19.00	21.38	54.61	217.34
D_3=95,238 plants ha^{-1}	173.73	1.59	21.00	16.80	17.55	47.55	168.93
Plant density (A)	NS	NS	**	NS	**	*	**
$LSD_{0.05(A)}$	-	-	1.78	-	3.14	15.30	30.33
Zero kg ha^{-1}	140.56	1.35	20.89	13.22	15.81	43.97	151.01
1.25 kg ha^{-1}	154.67	1.50	22.22	16.11	17.72	45.26	178.66
2.50 kg ha^{-1}	164.44	1.66	24.00	18.56	21.43	54.42	222.92
3.75 kg ha^{-1}	177.78	1.78	26.11	21.67	24.62	66.58	244.16
5.00 kg ha^{-1}	192.56	2.06	27.78	24.00	25.82	71.83	261.83
Humic acid (B)	**	**	**	**	**	**	**
$LSD_{0.05(B)}$	8.91	0.17	1.55	1.50	1.49	6.92	18.78

Interaction effects:

The interaction of plant density and humic acid level had no significant effects on all studied sunflower parameters in both seasons except the head diameter and leaf dry weight $plant^{-1}$ only in the second season (Table 2). The highest head diameter and leaf dry weight were recorded at humic acid applied role of 5 kg ha^{-1} under all plant density level.

2. Yield and Yield Components

Plant density effects.

The plant density level of sunflower significantly had an influence on all yield and its components in booth seasons, except the biological yield ha^{-1} in the first season (Table 3). The plant spacing (low plant density D_1= 47,619 plant ha^{-1}) produced the highest seed yield $plant^{-1}$ and the lowest biological yield ha^{-1} in both growth seasons. Seed, oil and protein yields ha^{-1} were significantly affected by the plant density. The plant density D_2 (71,428 plant ha^{-1}) significantly surpassed the other two plant densities (D_1 and D_3) by 15.59 and 42.16%, respectively, in the first season and by 19.37 and 50.18%, respectively, in the second one for the seed yield ha^{-1}. The same trend was observed in both seasons for oil and protein yields ha^{-1}. These results are in a good line with those reported by (Ibrahim (2012), Awais *et al*., (2013) Ali *et al*., (2014) and Hatami (2017). They mentioned that the increased density of plant population density increased seed, oil and protein yields per unit area. However, the opposite trend was observed by Ali *et al*., (2007), Diepenbrock *et al*., (2007), Zarei *et al*., (2011), Radwan *et al*., (2013) and Baghdadi *et al*., (2014),

Humic substance effects:

The results in Table 3 indicate that increase in humic acid applied level significantly increased yield and its components of sunflower in both seasons. The maximum values of seed yield $plant^{-1}$; biological, seed oil and protein yields ha^{-1} were recorded with adding 5 kg ha^{-1} of humic acid as soil application. Humic acid can influence the plant growth both in direct and indirect ways. Indirectly, it improves physical, chemical and biological properties of the soil. However, directly, it increases the chlorophyll content, accelerates plant respiration and hormonal growth responses, penetration through plant membranes, etc. These effects of humic acid operate singly or in integration. These results are in agreement with those obtained by Hai and Mir (1998) on wheat and rice, Rajpar *et al.,* (2011) on canola, Saadati and Baghi (2014) on chickpea, Kaya *et al.,* (2005) on common bean. and Yildirim (2007) on tomato.

Table 3. Main effects of plant density and humic acid on yield and its components of sunflower grown in 2015 and 2016seasons.

	Seed yield plant^{-1} (g)	Biological Yield ha^{-1} (ton)	Seed yield ha^{-1} (kg)	Oil yield ha^{-1} (kg)	Protein yield ha^{-1} (kg)
			2015 season		
D_1=47,619 plants ha^{-1}	70.14	6.03	2169.62	1065.30	206.33
D_2=71,428 plants ha^{-1}	58.94	6.31	2507.92	955.28	253.24
D_3= 95,238 plants ha^{-1}	47.84	6.74	1764.17	736.53	186.50
Plant density (A)	*	NS	**	**	**
$LSD_{0.05(A)}$	12.26	NS	192.90	30.07	27.88
Humic Substance (B)	**	**	**	**	**
Zero kg ha^{-1}	45.13	4.72	1504.90	598.94	129.26
1.25 kg ha^{-1}	52.14	5.43	1920.70	816.38	184.30
2.50 kg ha^{-1}	59.28	6.16	2215.38	953.18	224.83
3.75 kg ha^{-1}	66.69	7.03	2422.79	1056.71	246.10
5.00 kg ha^{-1}	71.63	8.45	2670.34	1169.99	292.30
Humic acid (B)	**	**	**	**	**
$LSD_{0.05(B)}$	5.41	0.79	105.05	25.51	13.26
			2016 season		
D_1=47,619 plants ha^{-1}	69.97	5.43	1800.29	909.81	174.45
D_2=71,428 plants ha^{-1}	55.03	5.89	2149.00	789.24	216.94
D_3= 95,238 plants ha^{-1}	45.85	6.41	1430.95	606.47	150.46
Plant density (A)	*	**	**	**	**
$LSD_{0.05(A)}$	12.30	0.46	165.89	34.94	16.72
Zero kg ha^{-1}	42.34	4.35	1188.27	476.77	108.87
1.25 kg ha^{-1}	51.01	4.74	1582.65	657.58	149.00
2.50 kg ha^{-1}	57.69	5.60	1891.34	814.80	187.17
3.75 kg ha^{-1}	63.90	6.85	2083.07	911.33	218.62
5.00 kg ha^{-1}	69.81	8.01	2221.71	982.06	239.42
Humic acid (B)	**	**	**	**	**
$LSD_{0.05(B)}$	3.55	0.96	112.33	26.64	10.97
A x B	**	NS	NS	NS	NS

Interaction effects:

Regarding plant density X humic acid interaction, the results revealed that the seed yield ha^{-1} in the first season and seed yield plant^{-1} in the second one were significantly affected. Sunflower grown at plant densities D_2 (71,428 plants ha^{-1}) and D_1 (47,619 plants ha^{-1}) showed significantly higher seed yield (71.63 and 69.81 g plant^{-1}, respectively) when treated by 5 kg ha^{-1} of humic acid in the first and second seasons respectively.

Oil content and nutrient uptakes

Plant density effects:

The plant density had significant effects on seed oil and protein contents as well as the uptakes of macro (N, P, K and Mg) and micro nutrients (Mn, Zn and Fe) by sunflower plants (Table 4 and 5). However, its effect was not significant on leaf uptakes of N, P, K, Mg, and Zn in the first season and the seed uptake of Zn in the second one. Meanwhile, seed oil content was significantly affected by the plant density only in the first season. The plant density D_2 recorded the maximum values except seed oil content in both seasons, seed K uptake and leaf Fe uptake in the first season but that of leaf P uptake was obtained by D_1in the second one. On the other side, plant density (D_3) gave the highest values of leaf uptakes of N, K, Mg, Mn and Zn in both seasons. Similar results have been reported by Ravichandran and Srinivasan (2017) who found that plant density (30x30 cm^2) single seedling with applying 200% recommended dose of NPK fertilizers (RDF) showed significantly higher uptakes of the N, P and K during 2015 and 2016 seasons (66.7 and 71.5 kg ha^{-1}, 21.3 and 24.5 kg ha^{-1}, as well as 145.3 and 169.2 kg ha^{-1}, respectively) compared to that of 60x30 cm with single seedling with adding, 100% of the RDF (34.5 and 38.2 kg ha^{-1}, 11 and 12.3 kg ha^{-1}, as well as 76.9 and 86.2 kg ha^{-1}, respectively, during 2015 and 2016 seasons). It was noticed that the higher nutrient uptake, with using the higher plant population level is attributed to more below and aboveground competition for nutrients and all the applied resources are effectively utilized. On the other hand, Al-Thabet (2006), Rauf *et al.*, (2012) Awais *et al*., (2013) and Yasin *et al*., (2013) mentioned that the plant density did not have any significant effect on oil or protein content of sunflower.

Humic acid effects:

The humic acid exerted high significant effects on seed oil and protein contents and the uptakes of the studied macro-and micro nutrients by sunflower plants (Table 4 and 5). The Increase in the humic acid level significantly increased the seed oil and protein content, macro- and micro-nutrient uptakes (N, P, K, Mg, Mn, Zn and Fe) of sunflower leaves and seeds. This effect may be related to the role of humic acid in soils and plants. The humic acid is the active constituent of organic humus, which can play a very important role in soil conditioning and plant growth. Physically, it promotes a good soil structure and increases the water holding capacity of the soil; biologically, it enhances the growth of beneficial soil organisms; chemically, it serves as an adsorption and retention complex for inorganic plant nutrients (Fahramand *et al.,* 2014). Also, MacCarthy *et al.* (2001) indicated that humates enhance nutrient uptake, improve soil structure, and increase the yield and quality of various crops. In addition to, Tahir *et al.,* (2011) on wheat, Rajpar *et al.,* (2011) and Ali *et al*., (2014), on canola reported that increasing applied the level of humic acid caused an increment in the oil, protein, N, P, K, and Fe contents. The same trend was also, observed by Tan and Nopamornbodi (1979) on maize, Saruhan *et al.,* (2011) on *Panicum miliaceum* L., Rauthan and Schnitzer (1981) on cucumber, Kaya *et al.*, (2005) on common bean and Tahir *et al.* (2011) on wheat .

Table 4. Main effects of plant density and humic acid on seed oil and protein contents and some macro-nutrients uptakes of sunflower grown in 2015 and 2016 seasons.

	Oil %	Protein %	N		P		K		Mg	
			Kg ha^{-1}							
			leaves	seed	leaves	seed	leaves	seed	leaves	seed
2015 season										
D_1=47,619 plants ha^{-1}	43.83	19.52	114.70	33.01	752.84	694.75	106.29	33.28	15.35	21.76
D_2=71,428 plants ha^{-1}	42.25	20.81	101.87	40.52	855.09	788.05	114.07	27.92	15.33	24.86
D_3=95,238 plants ha^{-1}	41.43	21.56	122.27	29.84	822.19	550.25	121.78	22.16	18.25	17.56
Plant density (A)	*	**	NS	**	NS	**	NS	**	NS	**
$LSD_{0.05(A)}$	0.65	0.89	-	4.46	-	21.38	-	2.31	-	2.00
Zero kg ha^{-1}	39.85	18.00	66.26	20.68	487.42	453.51	73.35	15.25	8.31	13.58
1.25 kg ha^{-1}	42.42	20.00	91.27	29.49	549.38	577.68	85.57	22.47	11.04	18.10
2.50 kg ha^{-1}	42.85	21.17	110.17	35.97	585.69	717.33	100.50	28.64	14.01	21.71
3.75 kg ha^{-1}	43.64	21.20	132.49	39.38	936.59	784.55	136.17	33.84	20.11	25.12
5.00 kg ha^{-1}	43.75	22.78	164.54	46.77	1491.13	855.34	174.66	38.73	28.07	28.47
Humic acid (B)	**	**	**	**	**	**	**	**	**	**
$LSD_{0.05(B)}$	0.79	0.95	16.86	2.12	59.68	15.92	17.79	1.34	2.32	1.00
A x B	*NS*	*NS*	**	*	**	**	*NS*	**	**	**
2016 season										
D_1=47,619 plants ha^{-1}	43.50	19.97	102.25	27.91	1153.18	577.57	99.66	38.84	14.42	17.58
D_2=71,428 plants ha^{-1}	42.12	20.77	108.59	34.71	1123.50	746.52	105.06	42.46	14.60	21.49
D_3=95,238 plants ha^{-1}	41.90	21.62	123.17	24.07	1054.28	461.52	124.75	28.34	17.28	13.51
Plant density (A)	*NS*	*	*	**	*	**	**	**	**	**
$LSD_{0.05(A)}$	-	0.83	12.49	2.68	27.36	19.72	9.32	3.48	0.62	1.72
Zero kg ha^{-1}	39.95	19.24	76.49	17.42	738.13	371.00	71.66	20.25	8.37	10.61
1.25 kg ha^{-1}	41.61	19.69	85.16	23.84	808.89	513.20	81.71	30.92	11.34	14.13
2.50 kg ha^{-1}	43.10	20.65	108.20	29.95	1189.61	611.01	99.67	38.74	13.92	17.89
3.75 kg ha^{-1}	43.65	21.88	130.25	34.98	1331.77	699.44	127.07	45.54	19.48	21.55
5.00 kg ha-1	44.21	22.47	156.61	38.31	1483.22	781.38	169.01	47.30	24.07	23.46
Humic acid (B)	**	**	**	**	**	**	**	**	**	**
$LSD_{0.05(B)}$	0.55	0.79	11.64	1.76	50.34	17.51	10.15	2.23	1.48	1.06
A x B	*NS*	*NS*	**	*NS*	**	**	**	**	**	*NS*

Table 5. Main effects of plant density and humic acid on some micro-nutrients uptakes of sunflower grown in 2015 and 2016 seasons.

	Mn		Zn		Fe	
			Kg ha^{-1}			
	leaves	seed	leaves	seed	leaves	seed
2015 season						
D_1=47,619 plants ha^{-1}	115.91	15.10	103.13	40.85	1052.99	110.49
D_2=71,428 plants ha^{-1}	165.00	18.34	119.64	44.16	688.61	138.65
D_3=95,238 plants ha^{-1}	175.90	11.48	128.72	30.23	939.78	94.27
Plant density (A)	*	**	*NS*	**	*	**
$LSD_{0.05(A)}$	38.08	1.44	-	3.36	218.12	11.07
Zero kg ha^{-1}	90.39	9.46	79.25	24.99	642.90	66.35
1.25 kg ha^{-1}	115.02	13.57	97.12	34.82	684.93	100.63
2.50 kg ha^{-1}	137.72	15.29	118.28	39.84	740.55	116.95
3.75 kg ha^{-1}	179.72	16.37	125.62	44.14	1161.91	126.44
5.00 kg ha^{-1}	238.50	19.82	165.56	48.28	1238.67	161.99
Humic Substance (B)	**	**	**	**	**	**
$LSD_{0.05(B)}$	17.22	0.77	15.33	1.87	132.09	6.93
A x B	**	**	**	**	**	**
2016 season						
D_1=47,619 plants ha^{-1}	161.51	11.52	123.83	29.59	1696.42	89.45
D_2=71,428 plants ha^{-1}	171.51	15.95	125.74	37.28	1462.35	113.68
D_3=95,238 plants ha^{-1}	198.15	10.39	134.75	26.26	1790.15	87.91
Plant density (A)	**	**	*	*NS*	**	**
$LSD_{0.05(A)}$	11.32	1.57	9.49	-	152.92	8.14
Zero kg ha^{-1}	118.13	7.28	76.49	16.61	1202.62	42.40
1.25 kg ha^{-1}	142.17	10.94	100.30	25.99	1286.79	68.70
2.50 kg ha^{-1}	165.81	12.96	125.22	33.62	1933.48	88.27
3.75 kg ha^{-1}	209.59	15.09	142.62	37.47	1871.89	122.68
5.00 kg ha^{-1}	249.64	16.83	195.90	41.51	1953.43	163.04
Humic Substance (B)	**	**	**	**	**	**
$LSD_{0.05(B)}$	16.63	0.90	12.42	3.33	182.50	18.11
A x B	**	*	**	*	**	*NS*

Effect of the interaction:

It is clear from the data given in Tables (6 and 7) that nutrient uptake of macro- and micro-elements were significantly affect by the plant density x humic substance interaction except leaves K uptake in the first season and seed Fe and Mg uptake in the second one. Application of 5 kg ha^{-1} humic substance for D_2 (71,428 plants ha^{-1}) or D_1 (47,619 plants ha^{-1}) gave the highest nutrient uptake in both seasons.

Table 6. Interaction effects of between plant density and humic acid on seed oil and protein contents, and N, P, K and Mg uptakes of sunflower.

	Seed oil (%)	Seed Protein (%)	N (%)		P (%)		K (%)		Mg (%)	
			leaves	seed	leaves	seed	leaves	seed	leaves	seed
2015 season										
A_1 x B_1	41.02	17.35	62.59	20.29	548.24	442.01	73.54	20.09	7.88	12.44
A_1 x B_2	45.58	18.71	103.02	28.44	526.81	593.96	73.97	25.86	10.93	17.92
A_1 x B_3	43.47	19.48	87.76	34.18	645.65	769.94	94.35	36.64	13.76	22.83
A_1 x B_4	44.30	19.17	130.31	35.80	1012.00	806.83	122.80	41.08	20.92	24.91
A_1 x B_5	44.77	22.88	189.80	46.36	1031.52	861.00	166.80	42.72	23.24	30.69
A_2 x B_1	39.20	17.88	74.83	27.52	351.20	595.05	68.95	17.98	6.44	19.16
A_2 x B_2	41.13	20.65	81.37	36.13	487.63	673.41	81.64	23.97	9.52	22.10
A_2 x B_3	43.26	21.67	116.78	43.27	395.46	884.75	113.33	27.44	11.49	25.42
A_2 x B_4	43.48	21.35	114.33	44.21	811.14	844.63	130.59	33.86	16.55	27.36
A_2 x B_5	44.18	22.52	122.07	51.47	2230.05	942.40	175.83	39.34	32.62	30.27
A_3 x B_1	39.34	18.77	61.37	14.23	562.82	323.47	77.56	10.69	10.59	9.12
A_3 x B_2	40.54	20.62	89.43	23.90	633.69	465.66	101.10	17.57	12.66	14.29
A_3 x B_3	41.82	22.38	125.97	30.48	715.97	497.30	93.82	21.85	16.79	16.88
A_3 x B_4	43.15	23.08	152.83	38.11	986.63	702.19	155.11	26.59	22.85	23.09
A_3 x B_5	42.31	22.96	181.75	42.48	1211.83	762.61	181.33	34.12	28.35	24.45
F-test	NS	NS	**	*	**	**	NS	**	**	**
$LSD_{0.05(AB)}$	NS	NS	29.20	3.67	103.37	27.57	NS	2.31	4.01	1.74
2016 season										
A_1 x B_1	41.00	19.02	74.16	17.27	879.57	386.55	58.31	21.65	7.30	10.15
A_1 x B_2	42.94	18.83	89.54	22.00	855.43	491.47	79.47	29.49	10.27	13.43
A_1 x B_3	44.79	19.42	92.52	29.00	1358.69	584.67	85.66	38.15	10.88	18.71
A_1 x B_4	43.98	20.81	119.62	33.84	1281.82	723.66	121.09	52.62	20.82	22.39
A_1 x B_5	44.77	21.77	135.42	37.45	1390.40	701.52	153.78	52.30	22.83	23.16
A_2 x B_1	40.40	18.79	67.87	22.00	653.66	460.46	79.09	24.21	6.82	14.04
A_2 x B_2	40.79	19.42	68.00	29.28	910.13	659.21	68.00	37.48	10.27	17.99
A_2 x B_3	41.68	21.10	103.66	35.53	1300.15	763.98	100.79	50.57	14.41	21.64
A_2 x B_4	43.99	22.08	126.10	41.67	1223.45	845.32	130.08	51.20	19.33	25.83
A_2 x B_5	43.72	22.44	177.33	45.07	1530.10	1003.66	147.35	48.85	22.19	27.95
A_3 x B_1	38.45	19.90	87.42	12.99	681.15	266.00	77.60	14.88	10.99	7.61
A_3 x B_2	41.10	20.83	97.93	20.24	661.11	388.91	97.67	25.79	13.47	10.97
A_3 x B_3	42.82	21.44	128.41	25.31	909.97	484.37	112.55	27.50	16.48	13.32
A_3 x B_4	42.98	22.73	145.01	29.42	1490.03	529.35	130.04	32.79	18.28	16.41
A_3 x B_5	44.15	23.19	157.07	32.40	1529.16	638.98	205.88	40.74	27.18	19.27
F-test	*NS*	*NS*	**	*NS*	**	**	**	**	**	*NS*
$LSD_{0.05(AB)}$	NS	NS	20.16	NS	87.18	30.34	17.58	3.86	2.57	NS

Table 7. Interaction effects of plant density and humic acid on Mn, Zn and Fe uptakes by sunflower.

	Mn ($mgkg^{-1}$)		Zn ($mgkg^{-1}$)		Fe ($mgkg^{-1}$)	
	leaves	seed	leaves	seed	leaves	seed
2016 season						
A_1 x B_1	39.18	8.99	80.02	25.21	1150.80	72.39
A_1 x B_2	96.07	14.92	79.80	40.97	667.73	110.27
A_1 x B_3	125.40	17.66	88.03	43.32	723.80	111.96
A_1 x B_4	163.30	15.31	118.45	41.95	1554.20	112.17
A_1 x B_5	155.60	18.62	149.33	52.82	1168.40	145.67
A_2 x B_1	108.72	12.99	80.38	32.14	256.17	87.57
A_2 x B_2	122.00	15.64	103.80	38.06	486.40	122.77
A_2 x B_3	114.43	17.23	124.13	46.83	744.17	134.17
A_2 x B_4	158.20	19.41	94.23	49.55	875.00	133.18
A_2 x B_5	321.67	26.41	195.67	54.25	1081.33	215.57
A_3 x B_1	123.26	6.39	77.35	17.64	521.73	39.10
A_3 x B_2	127.00	10.15	107.75	25.44	900.67	68.84
A_3 x B_3	173.33	10.98	142.68	29.37	753.68	104.72
A_3 x B_4	217.67	15.46	164.17	40.92	1056.53	133.97
A_3 x B_5	238.23	14.44	151.67	37.78	1466.27	124.72
F-test	**	**	**	**	**	**
$LSD_{0.05(AB)}$	29.83	1.33	26.55	3.24	228.78	12.01
2016 season						
A_1 x B_1	117.39	6.67	77.53	15.35	1138.25	40.51
A_1 x B_2	111.87	10.31	91.03	25.75	727.73	55.90
A_1 x B_3	108.03	12.57	130.12	35.09	2256.48	75.76
A_1 x B_4	230.90	13.62	126.90	33.94	2348.03	116.29
A_1 x B_5	239.35	14.41	193.55	37.83	2011.61	158.82
A_2 x B_1	94.15	9.76	45.84	22.18	1276.49	46.88
A_2 x B_2	148.62	14.42	101.33	28.48	1215.95	86.87
A_2 x B_3	184.34	16.11	128.24	38.87	1811.39	105.32
A_2 x B_4	191.94	18.76	145.57	43.62	1330.77	135.39
A_2 x B_5	238.49	20.72	207.72	53.24	1677.15	193.97
A_3 x B_1	142.84	5.39	106.11	12.30	1193.13	39.81
A_3 x B_2	166.01	8.08	108.54	23.74	1916.70	63.32
A_3 x B_3	205.05	10.21	117.30	26.91	1732.56	83.73
A_3 x B_4	205.92	12.90	155.39	34.86	1936.86	116.35
A_3 x B_5	271.07	15.36	186.42	33.47	2171.53	136.33
F-test	**	*	**	*	**	*NS*
$LSD_{0.05(AB)}$	28.80	1.55	21.51	5.77	316.11	-

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تأثير كلا من مسافات الزراعة واستخدام حمض الهيوميك علي المحصول ومكوناته وامتصاص العناصر الغذائية لنباتات زهرة الشمس المنزرعة في الاراضي الحديثة الاستصلاح

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أجريت هذه الدراسة بمزرعة كلية الزراعة بمنطقة دمو بمحافظة الفيوم خلال موسمين هما صيفي ٢٠١٥ وصيفي ٢٠١٦ لبيان تأثير كلا من مسافات الزراعة واستخدام حمض الهيوميك علي كلا من محتوي الزيت وامتصاص العناصر وصفات النمو الخضري لنباتات زهرة الشمس، وكان التصميم الاحصائي المستخدم هو القطاعات الكاملة العشوائية المنشقة مرة واحدة باستخدام ٣ مكررات وكانت مسافات الزراعة هي ف١ (٧٠سم X ٣٠سم)، ف٢ (٧٠سمX ٢٠سم)، ف٣ (٧٠سمX ١٥سم) هي القطع الرئيسية علي ان تتضمن كل معاملة ٥ مستويات من حمض الهيوميك وكانت علي النحو التالي (٠: ١.٢٥: ٢.٥: ٣.٧٥: ٥ كجم/هكتار) كقطع منشقة. وقد اشارت النتائج الي ان مسافة الزراعة ف١ (٧٠سمX ٣٠سم) اعطت أعلي النتائج لكلا من صفات أطوال النباتات وعدد الاوراق/نبات والوزن الجاف لكلا من الاوراق والسيقان والاقراص وأيضا لمحصول البذرة لكل نبات، بينما مسافة الزراعة ف٢ (٧٠سمX٢٠سم) سجلت أعلي محصول بذرة/هكتار. وكانت معاملة استخدام ٥ كجم/هكتار من حمض الهيوميك قد سجلت أعلي القيم لكل من صفات النمو الخضري والمحصول ومكوناته مثل محتوي الزيت وامتصاص العناصر الغذائية وذلك في كلا الموسمين. وبناءا علي ذلك فان أعلي محصول بذرة سجل من خلال مسافة الزراعة ف٢ (٧٠سمX ٢٠سم) مع استخدام ٥ كجم من حمض الهيوميك/ هكتار كاضافة ارضية.