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Role of Humic Acid in Growth, Yield, Yield Component and Fatty Acid Traits of four Sunflower Genotypes (*Helianthus annuus* L.)

Shaee Adeeb Ghareeb[1], Rabar Fatah Salih[2]* and Rawaz Jalal Hama Ali[3]

[1,3] Department of Biotechnology and Crop Science, College of Agricultural Engineering Sciences, University of Sulaimani, Sulaimani, Kurdistan, Iraq.
[2] Department of Field Crops and Medicinal Plants, College of Agricultural Engineering Sciences, University of Salahaddin-Erbil, Erbil, Kurdistan Region, Iraq.
shaee.gharib@univsul.edu.iq , rabar.salih@su.edu.krd , rawaz.hamaali@univsul.edu.iq

KEY WORDS:
Sunflower, Oilseed, Non-oilseed, Humic acid, Growth, Yield, Fatty acids.

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ABSTRACT

The field experiment was carried out at Qlyasan in the Sulaimani region during the summer season of 2022-2023. It was aimed to investigate the effect of different levels of humic acid on growth, yield and yield components and fatty acids of four sunflower genotypes (Oilseed and Non-oilseed). The first factor included sunflower genotypes; (HS360, Flamme, Dakota and Pionner), while the second factor involved different levels of humic acid, (H0, H1 and H2 that responded 0, 20 and 40 kg. ha^{-1}), respectively. The results showed that, genotypes significantly affected all traits except fatty acids. Pionner *var*. surpassed others by having the highest values of growth traits; plant height, stem diameter, head diameter and number of seeds per head were by (171.52, 2.07, 17.86 cm and 1314.44 NS/head), respectively. While, Dakota *var.* was surpassed others in yield and yield component traits; 1000 seed weight, seed, oil and protein yields were by (87.93 g, 3.75, 160.09 and 74.54 t. ha^{-1}), respectively. Generally, humic acid at the level of 40 kg. ha^{-1} (H2) significantly enhanced growth and yield parameters taken from this present study, it also could be said that it had a great impact on fatty acids in sunflower seeds, while only linoleic, oil and protein percentage improved. Additionally, the interaction between both factors also significantly affected all traits except of some fatty acids were not. Interaction between all genotypes to 40 kg. ha^{-1} humic acid (V1H2, V2H2, V3H2 and V4H2), were mostly superior of all traits when compared to other treatments. Finally, it could be concluded that humic acid had the important role of enhancing growth, quantity and quality of both sunflower types (Oilseed and Non-oilseed).

دور حمض الهيوميك في صفات النمو والحاصل ومكوناته والأحماض الدهنية لأربعة تراكيب وراثية من زهرة الشمس (*Helianthus annuus* L)

شايي اديب غريب[١] رابر فتاح صالح[٢] رەوەز جلال حمه علي[٣]
[١ و ٣] (قسم التكنولوجيا الحياتية وعلم المحاصيل ،كلية علوم الهندسة الزراعية، جامعة السليمانية، السليمانية، العراق.)
[٢] (قسم المحاصيل الحقلية والنباتات الطبية ،كلية علوم الهندسة الزراعية، جامعة الصلاح الدين، اربيل، العراق.)

الخلاصة

أجريت التجربة الحقلية في منطقة قليسان في مدينة السليمانية خلال الموسم الصيفي ٢٠٢٢-٢٠٢٣. لغرض دراسة تأثير مستويات مختلفة من حامض الهيوميك في النمو والحاصل ومكوناته والأحماض الدهنية لأربعة أصناف من زهرة الشمس (زيتية وغير زيتية). العامل الأول يمثل تراكيب وراثية زهرة الشمس (٣٦٠HS و Flamme وDakota و Pionner) بينما العامل الثاني يمثل مستويات مختلفة من حامض الهيوميك H٠) وH١ و H٢ ، ٠و٢٠و٤٠ كغم هكتار$^{-١}$) على التوالي. أظهرت النتائج أن تراكيب وراثية أثرت معنويا في جميع الصفات ما عدا الأحماض الدهنية. تفوق الصنف Pionner بأعلى القيم لصفات النمو حيث بلغ ارتفاع النبات وقطر الساق وقطر قرص وعدد البذور لكل رأس (١٧١.٥٢، ٢.٠٧، ١٧.٨٦ سم و ١٣١٤.٤٤. عدد البذور/قرص) على التوالي. بينماتفوق صنف Dakota في صفات الحاصل ومكوناته؛ وبلغ وزن ١٠٠٠ بذرة حاصل البذور والزيت والبروتين (٩٣.٨٧غم، ٣.٧٥، ١٦٠.٠٩و٧٤.٥٤طن هكتار$^{-١}$) على التوالي. عموما حمض الهيوميك عند مستوى ٤٠ كغم. الهكتار$^{-١}$(H ٢) ادى الى تعزيز صفات النمو والإنتاجية بشكل ملحوظ من هذه الدراسة الحالية ، ويمكن القول أيضًا أنه كان له تأثير كبير على الأحماض الدهنية في بذور زهرة الشمس، بينما فقط نسبة اللينوليك والزيت والبروتين تحسنت بشكل ثابت. بالإضافة إلى ذلك فإن التداخل بين كلا العاملين أثر أيضاً معنوياً على جميع الصفات باستثناء بعض الأحماض الدهنية التي لم تكن كذلك. كانت تداخل جميع تراكيب وراثية مع المستوى ٤٠ كغم هكتار$^{-١}$ حمض الهيوميك (V1H2، V2H2 ، V3H2 ،V4H ٢ (متفوقاً في الغالب للصفات جميعها بالمقارنة مع المعاملات الأخرى. وأخيرا يمكن الاستنتاج أن حمض الهيوميك كان له دور مهم في تعزيز النمو وكمية ونوعية كلا النوعين من زهرة الشمس (الزيتية وغير الزيتية).

كلمات مفتاحية: زهرة الشمس، بذور الزيتية، بذور غير الزيتية، حامض الهيومك، النمو، الحاصل، الاحماض الدهنية

INTRODUCTION

Helianthus annuus is botanical name of the sunflower plant, which is the fourth annual seed oil crop in the world, moreover it can be cultivated in a wide range of environmental circumstances (Hatami, 2017). Also, the world regarded the sunflower plant is one of the most important oil crops and it comes as the second crop after soybean in Iraq (Al Myali *et al.,* 2020). High percentage of oil (40-50 %) and protein 26 % could find in sunflower seeds (Petraru *et al.,* 2021). Its oil contains low cholesterol due to this reason; it becomes a vital basis of the human diet (Sumon *et al.,* 2021).

Previous studies showed the impact of using different types and levels of humic acid for improving growth, quality and quantity not only for sunflower plants but also for other crops. Tests have shown that humic acid enhanced the production of protein, vitamins and sugar in plants which was by affecting of photosynthesis and then increasing the yield and quality of the product (Sharif *et al.*, 2002). Hatami (2017) also stated that zinc and humic acid added to the sunflower plant improved yield in drought stress, by increasing evaluations of the diameter and number of seeds per head and weight of grain. Humic acid also can maximize crop yield and quality due to stimulating cellular membrane permeability, cellular photosynthesis and respiration, and uptake and translocation of soil nutrients (Osman and Rady 2012; Hemida *et al.,* 2017). Additionally, humic acids is a vital soil component, which has the great role of increasing nutrient supply and has positive impacts on biological and physicochemical properties of the soils (Ullah *et al.,* 2018). Furthermore, it helps in protein biosynthesis, stimulates root cell elongation, activates helpful microorganisms in the soil, and acts a phytohormones, which have the role on the plants (Pizzeghello *et al.,* 2013; Liu *et al.,* 2019; *Shen et al.,* 2020).

Teileb and Mourad (2019) reported that, seed yield percentage and quality of sunflower plants were enhanced by applying humic acid. Another study stated that the application of humic acid may provide a useful enhancement to reduce the harmful influences of salinity stress on sunflower plants (Mourad *et al.,* 2020). From previous studies recommends that adding different levels and types of humic acid may improve the quantity and quality of nutrient components of kenaf leaves (Sultan and Salih, 2022).

This current study aimed to estimate the impact of different humic acid levels on growth, yield and yield components and fatty acids in seeds of four sunflower genotypes of Oilseed and Non-oilseed types.

MATERIALS AND METHODS

Study site:

The current study was done in the Qlyasan, which was located at the Governorate of Sulaimani in the Northeast of Iraq, on the border with Iran. Qlyasan is the Research Station of the Biotechnology and Crop Science Department, College of Agricultural Engineering Sciences, University of Sulaimani, located at (Latitude: 35° 34′ 17″ N, Longitude: 45° 22′ 00″ E, and altitude of 757 masl), 2 km northwest of Sulaimani city. "Garmin, GPS map 60 Cx. Experimental design:

A field experiment was carried out during the summer 2022 – 2023 season. The experiment included two factors; the first was seeds of four sunflower genotypes; HS360, Flamme, Dakota and Pionner, which were symbolized as (V1, V2, V3 and V4) respectively, while the all genotypes were from Bakrajo Agriculture Research Center in Sulaimani, Kurdistan, Iraq. All genotypes were planted in 2022, 1st of June (Figure 1). Different levels of humic acid (0, 20 and 40 kg. ha^{-1}), (BioHumic, 95% humic acid, 100% Soluble, USA, produced by: Plant's Choice; Batch number: 201211), which ware symbolized as (H0, H1 and H2), respectively added to the plants as a second factor. The field experiment was conducted using Randomized Complete Block Design with three replicates.

The area of the experimental unit was (1×1.5 m^2), and within each experimental unit, there were four lines. The length of the planted line was 1 m, with a distance of 50 cm between each line and 30 cm between plants within the same line. A distance of 1 m was left between experimental units and another meter was left between blocks. Two to three seeds were sown in each hole, and they were thinned to one plant which was two weeks after germination.

Figure 1. Sunflower seeds and heads of both types of oilseed and non-oilseed.

Studied traits:

Growth traits:

1. Plant height (cm)

The plant height was measured using a linear meter scale from the base of the stem to the point of stem insertion with a sunflower head and expressed (cm).

2. Stem diameter (cm)

The stem diameter was measured at the middle length of the plant using (Vernier caliper), and expressed (cm).

3. Head diameter (cm)

The diameter of the mature head was measured with a meter-tape across scale the center of the head in each treatment (cm).

4. Number of seeds per head

The number of full seeds from each harvested five sunflower heads in each plot was counted, and the average full seeds head^{-1} was recorded.

Yield and yield component traits:

1. 1000 seed weight (g)

Thousand seeds were selected randomly from threshed out of each treatment, then weighed and expressed in grams.

2. Seed yield (t. ha^{-1})

The seed weight of the five representative plants was added to the net plot seed weight, and later the average seed yield was converted to t. ha^{-1}.

3. Oil yield (t. ha^{-1})

The oil yield (t. ha^{-1}) is the product of oil (%) multiple to seed yield (t. ha^{-1}) as shown in equation (1).

$$\text{Oil yield}\ (t.ha^{-1}) = \text{Oil \%} \times \text{Seed yield}\ (t.ha^{-1}) \ldots (1)$$

4. Protein yield (t. ha^{-1})

The protein yield (t. ha^{-1}) is the product of protein (%) multiple to seed yield (t. ha^{-1}) as shown in equations (2 and 3). Salih, R.F. and Abdan, K.B., (2022).

$$Protein\ percent\ (\%) = Nitrogen\ \% \times 6.25 \ldots (2)$$

$$\text{Protein yield}\ (t.ha^{-1}) = \text{Protein \%} \times \text{Seed yield}\ (t.ha^{-1}) \ldots (3)$$

Seed quality traits:

Two grams of the harvested seeds of each treatment were powdered by electric blender. Digital Soxholet instrument was used for oil distillation, with n-hexane solvent (BDH, UK), (Ferreira-Dias *et al.,* 2003).

The oil content was calculated as the following equation (4):

$$Oil\ \% = \frac{W2-W1}{S} \times 100 \ldots (4) Oil\ \% = \frac{W2-W1}{S} \times 100 \ldots (4)$$

W1 = weight of empty flask (g)

W2 = weight of flask and the extracted oil (g)

S = weight of sample

Oil samples were kept in refrigerator until use for separation of fatty acids.

The sample was prepared according to the method approved by (AOAC 1995). 11.2 g of potassium hydroxide was dissolved in 100 ml of methanol to prepare methanolic potassium hydroxide. Then, 1 gm of fat was taken and then 8 ml of methanolic potassium hydroxide was added it was with 5 ml of hexane. Next, it was shaken quickly for 30 seconds, then the sample was left to separate into two layers. Finally, the samples were taken from the upper layer (hexane layer), which was contained the esterified fat and put into the device.

The fatty acid compounds were analyzed using a gas chromatography device (GC-2010) (Shimadzu model of Japanese origin), with a flame ionization detector (FID), and a capillary separation column (SE-30) with a length of (30 m × 0.25 mm) was used.

Soil analysis

Table 1 displays the physical and chemical properties of the soil taken from the experimental site. 0 to 30 cm was the depth of the soil to take the samples randomly in several places of the farm before it was divided into plots. Afterward, the soil was air dried and sieved through a 2 mm pore size sieve, which was in the laboratory. Then, physicochemical parameters were determined.

Table 1. Physicochemical properties of the soil samples from the study site.

Physicochemical Properties			
Physical properties	Sand	87	
	Silt	435	(g. kg^{-1})
	Clay	458	
	Texture	Silty Clay	
	pH	7.59	
	ECe	490	(µS. cm^{-1})
Chemical properties	O.M.	22.4	(g. kg^{-1})
	$CaCO_3$	304.3	
	N (total)	0.12	(%)
	P (available)	5.24	(Mg. kg^{-1})
	K (available)		(ppm)

Statistical analysis

All data were collected from thisstudy and statistically analyzed according to the technique of analysis of variance (ANOVA) for randomized complete block design, using IBM SPSS Statistics Program (20), the mean comparison was fulfilled according to Duncan multiple range test.

RESULTS AND DISCUSSION

1. Growth traits:

A. Influence of genotypes and humic acid on plant height (cm):

Plant height was significantly changed between genotypes and also was increased by increasing humic acid levels (Table 2). Pionner (V4) was surpassed other genotypes by having the highest plant high (171.52cm), followed by Dakota (V3), which was (162.01cm). While, the shortest plant high was found in HS360 (V1), by (90.48cm). As genotypes, humic acid applications caused to increase in plant height. The highest plant height was noted when 40 kg. ha^{-1} of humic acid was added to the plants (138.68cm). Despite that, the plant height in the control treatment was just about (136.20cm). These results show the impact of humic acid on plant high, which may be related to cell division and also improving photosynthetic process and might be caused to active soil microorganisms, and then it motivates the plant roots to easy nutrient absorption. As explained by several previous studies nutrient absorption by plant roots is closely related to the available nutrients and their ease of movement towards plant roots (Ouni *et al.*, 2014). This was due to adding humic acid to the soil, which enhanced the soil's biological activity and then caused to active some substances that improve the solubility of nutrients to be available to the plant roots (Belal *et al.*, 2019). Mekdad *et al.* (2021) indicated that the plant height of sunflower was significantly increased by adding humic acid.

Table 2. effect of genotypes and humic acid on growth traits.

Genotypes	Growth parameters			
	PH (cm)	SD (cm)	HD (cm)	NS/head
HS360 (V1)	90.48[d]	1.40[d]	17.36[b]	1222.89[b]
Flamme (V2)	125.47[c]	1.64[c]	16.46[c]	1236.11[b]
Dakota (V3)	162.01[b]	1.75[b]	16.78[c]	924.11[c]
Pionner (V4)	171.52[a]	2.07[a]	17.86[a]	1314.44[a]
Humic acid				
H0 (control)	136.20[b]	1.70[b]	16.61[c]	1112.25[c]
H1 (20 kg ha^{-1})	137.23[ab]	1.71[b]	17.08[b]	1174.67[b]
H2 (40 kg ha^{-1})	138.68[a]	1.73[a]	17.64[a]	1236.25[a]

PH= plant height, SD= stem diameter, HD= head diameter, NS/head= number of seeds per head

*Means with different letters differ significantly at ($p \leq 0.05$).

Figure 2 shows the interaction effects between genotypes and humic acid levels on plant height. The interaction of both factors was only found between the HS360 sunflower genotype to humic acid. The highest plant high was noted when 40 kg. ha^{-1} humic was added to the plants (V1H2). This result was strongly confirmed by the results of Teileb and Mourad (2019) who showed that highly significant interaction was found for plant height, when humic acid and mineral fertilizer were added to the sunflower plants. As mentioned previously, any significant was not recorded among humic acid levels Flamme, Dakota and Pionner. Generally, all interactions showed that the highest level of humic acid (H2; 40 kg. ha^{-1}), which caused to increase this growth parameter of sunflower plants.

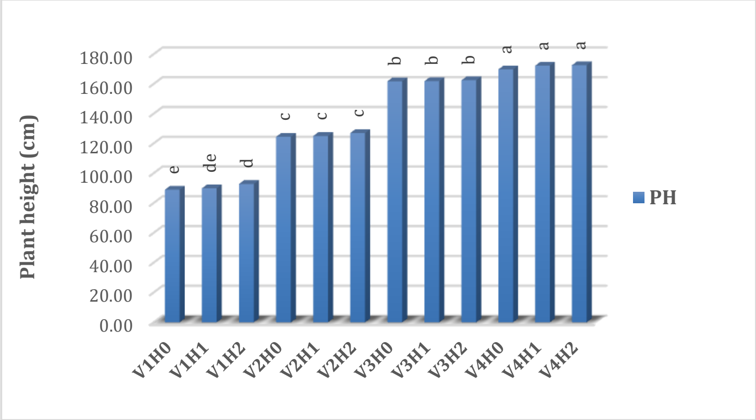

Figure 2. Effect of combination between genotypes and humic acid levels on plant height (cm). Means with different letters differ significantly at ($p \leq 0.05$).

B. effect of genotypes and humic acid on stem diameter (cm):

The stem diameter was another growth traits taken between treatments. Again, the biggest stem diameter was noted of Pionner genotype (2.07cm), which was compared to other genotypes. Additionally, 1.73 cm was the biggest stem diameter recorded when humic acid was applied to the plants by an amount of 40 kg. ha^{-1}, which was superior to 20 kg. ha^{-1} and also on control treatment (Table 2). As for plant height, the significance of stem diameter between genotypes and humic levels only recorded of HS360 genotype; V1H2 was taller than V1H1 and VIH0 (Figure 3). Highly significance was noted in the interaction treatment on stem diameter of sunflower genotypes with humic acid and mineral fertilizers (Teileb and Mourad 2019).

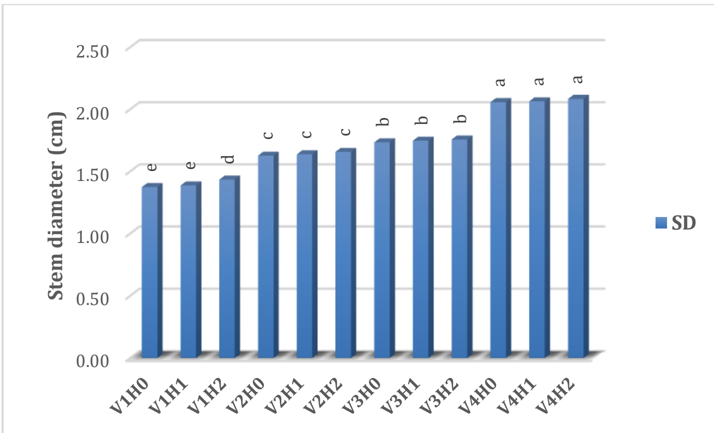

Figure 3. Effect of combination between genotype and humic acid levels on stem diameter (cm). Means with different letters differ significantly at ($p \leq 0.05$).

C. Influence of genotypes and humic acid on head diameter (cm):

Head diameter is one of the best growth traits of sunflower plant, since directly related to improved yield and yield components such as; the number of seeds per head, seed size, seed weight… etc. Because of that, improving this parameter is required by the agronomist and farmers also. Pionner surpassed the three other genotypes by having the biggest head diameter (17.86cm), followed by HS360 (17.36cm), as can be seen in the (Table 2). The head diameter was also improved when humic acid was added by 40 kg. ha^{-1} (17.64cm), while in the control treatment head diameter was recorded by (16.61cm), only. These results collaborate with Mahmood (2021) who stated that the differences among genotypes were highly significant in head diameter of the sunflower plant. Results of previous studies indicated that the Velko genotype surpass the Baroloro genotype in head diameter (Bapir and Mahmood (2022). Also, investigation of some sunflower genotypes and humic acid application indicated that both factors had significant effect on head diameter (Mourad *et al.,* 2020).

combination between genotypes and humic acid levels caused significant results in head diameter (Figure 4). So, the biggest head diameter was found in the interaction of Pionner to 40 kg. ha^{-1} of humic acid (18.53 cm), followed by HS360 to 40 kg. ha^{-1} of humic and Pionner again with 20 kg. ha^{-1} of humic by (18.17 and 18.07 cm), respectively. That's at a time, the smallest head diameter for all genotypes was noted in the control treatments.

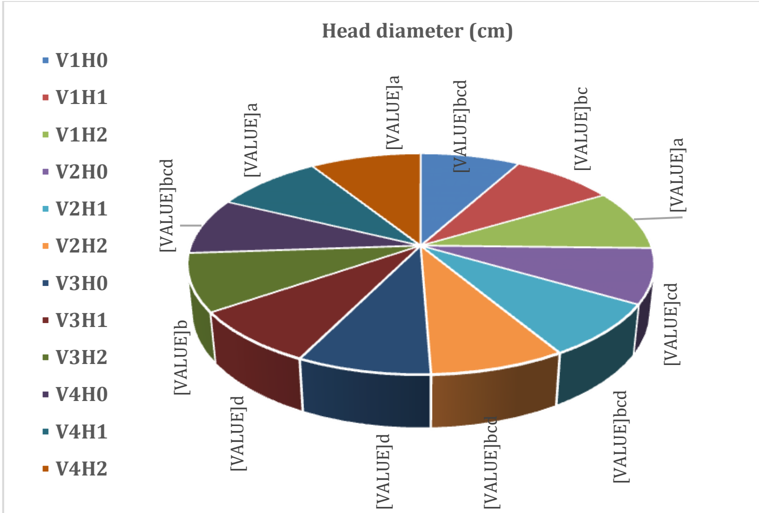

Figure 4. Effect of combination between genotypes and humic acid levels on head diameter (cm). Means with different letters differ significantly at ($p \leq 0.05$).

D. Effect of genotypes and humic acid on number of seeds/head:

The number of seeds per head (NS/head), was dramatically improved due to the genotypes effected and also added different levels of humic acid. This result may refer to the plants which have been the biggest head diameter as mentioned earlier; Pionner genotype surpassed other genotypes by having the best head diameter and also the highest level of humic acid was applied during this present study (40 kg. ha^{-1}), caused to improve head diameter, which relationship to increase the number of seeds per head. Pionner *var.* superior to others by recording the maximum number of seeds (1314.44 NS/head), while the minimum seed number noted from Dakota *var.* (924.11 NS/head). Just the same, 1236.25 was a seed number found when 40 kg. ha^{-1} of humic was added to the plants, which was greater compared to the outcomes of 20 kg. ha^{-1} and also to the control treatments (1174.67 and 1112.25 NS/head), respectively (Table 2). Results from this current study were supported by the results of Moghadam *et al.* (2014) who reported that the total number of seeds in the ears were significantly increased by adding humic acid.

Figure 5 shows the interaction effects of genotypes to different levels of humic acid, which significantly affected this growth parameter. The maximum seed number was found in the treatment (V4H2), followed by (V1H2 and V4H1), were by (1359.33, 1331.67 and 1324.33 NS/head), respectively. On the contrary, the minimum seed number was noted in the control treatments for all genotypes (V1H0, V2H0, V3H0 and V4H0), by (1106.33, 1191.33, 891.67 and 931.33 NS/head), respectively.

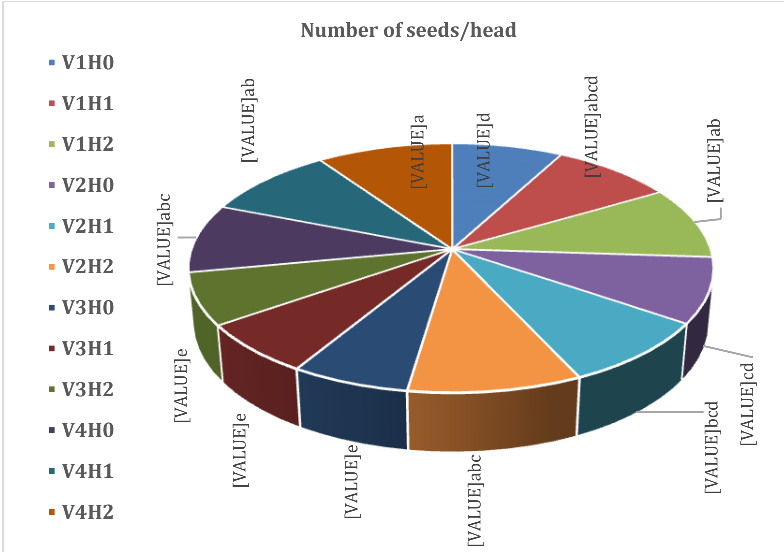

Figure 5. Effect of combination between genotypes and humic acid on number of seeds/head. Means with different letters differ significantly at (p ≤0.05).

2. Yield and yield components

A. Effect of genotypes and humic acid on 1000 seeds weight (g):

Significant differences between means of genotypes and humic acid levels were found in yield and yield component traits (Table 3). Dakota *var.* surpassed other genotypes of all yield traits, so the maximum values of 1000 seed weight, seed yield, oil, and protein yields were (87.93 g, 3.75, 160.09 and 74.54 t. ha^{-1}), respectively followed by HS360 *var.* were (72.49 g, 2.97, 126.56, 60.09 t. ha^{-1}), respectively. These results are supported by the outcomes of Bapir and Mahmood (2022) who concluded that, sunflower growth, yield and quality are impacted by genotypes. 1000 seeds weight was significantly changed according to the genotypes affected, so the sunflower Dea genotype was superior to others by having (57.22 g), of seed weight (Mahmood, 2021). Additionally, humic acid was also significantly affected these parameters. The maximum values were recorded when H2 (40 kg. ha^{-1}) added to the plants, which were so greater compared to the outcomes of (H1 and H0), treatments. These results confirmed that humic acid was really impacted to improve quantity parameters of sunflower pants.

Combination between both factors levels significantly improved 1000 seed weight of sunflower plants (Figure 6). Dakota *var.* with humic acid at the level of (40 kg. ha^{-1}), (V3H2) is superior to other genotypes by having the highest value (93.93 g). Generally, the smallest values were noted in all control treatments for all genotypes (VIH0, V2H0, V3H0 and V4H0), by (67.57, 59.03, 83.43 and 66.63 g), respectively. However, with increasing the amounts of humic acid also seed weight was increased, this was factual for whole treatments.

Table 3. Single effect of genotypes and humic acid on yield and yield component parameters.

genotypes	Yield and yield component parameters			
	SW (g)	SY (t ha^{-1})	OY (t ha^{-1})	PY (t ha^{-1})
V1	72.49^{b}	2.97^{b}	126.56^{b}	60.09^{b}
V2	62.80^{d}	2.79^{c}	118.52^{c}	55.13^{c}
V3	87.93^{a}	3.75^{a}	160.09^{a}	74.54^{a}
V4	69.99^{c}	2.41^{d}	103.14^{d}	49.42^{d}
Humic acid				
H0	69.17^{c}	2.81^{c}	118.29^{c}	52.19^{c}
H1	73.49^{b}	2.90^{b}	123.52^{b}	58.32^{b}
H2	77.25^{a}	3.23^{a}	139.42^{a}	68.87^{a}

V1= HS360, V2= Flamme, V3= Dakota, V4= Pionner, H0 (control), H1 (20 kg. ha^{-1}), H2 (40 kg. ha^{-1}), SW= 1000 seed weight, SY= seed yield, OY= oil yield, PY= protein yield

*Means with different letters differ significantly at ($p \leq 0.05$)

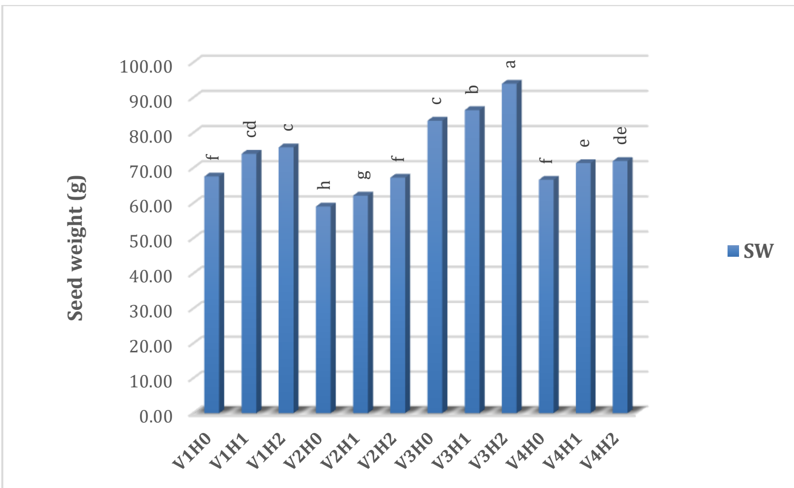

Figure 6. Effect of combination between genotypes and humic acid levels on 1000 seed weight (g). Means with different letters differ significantly at ($p \leq 0.05$).

B. Effect of genotypes y and humic acid on seed yield (t. ha^{-1}):

The single effect of each of genotype and humic acid levels significantly enhanced the seed yield of sunflower plants. Dakota *var.* and humic acid at the level of 40 kg. ha^{-1} are surpassed other treatment by (3.75 and 3.25 t. ha^{-1}), respectively (Table 3). Seed yield of sunflower genotypes significantly increased in Kanipanka and Qlyasan in the Governorate of Sulaimani, so Velko was surpassed others in both locations (Mahmood *et al.*, 2019). The maximum seed yield t. ha^{-1}, was also again noted in the interaction treatment (V3H2), by (4.08 t. ha^{-1}). While, the minimum seed yield was recorded in all control treatments. This was a proof showed the importance of humic as a nutrient to the plants (Figure 7). These results were in agreement with those obtained by (Mourad *et al.*, 2020).

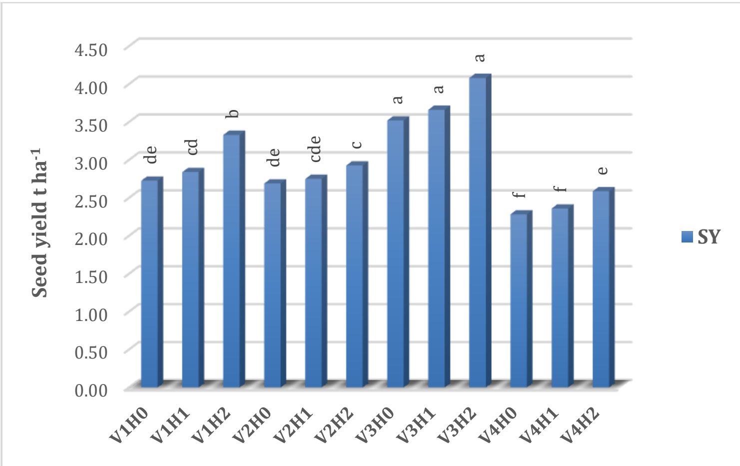

Figure 7. Effect of combination between genotypes and humic acid levels on seed yield (t. ha^{-1}). Means with different letters differ significantly at ($p \leq 0.05$).

C. Effect of genotypes and humic acid on oil and protein yields (t. ha^{-1}):

Oil and protein components are the important chemicals in the seeds of sunflower which are different according to the genotypes. Changing of the amounts of each other means that changing of quality and quantity of products, may cause to improve the end uses. Oil and protein yields were statically changed between genotypes and also humic acid levels (Table 3). These results are in agreement with the findings by Heydari *et al.* (2021), who reported that foliar application of humic acid increased 1000-seed weight, seed yield and oil yield of safflower crop. So, figure 8 shows the improvement for both chemicals in seeds of sunflower plants. The maximum yields of oil and protein were recorded in the interaction treatment (V3H2), by (176.34 and 85.67 %), respectively, while the minimum values of both parameters were (96.46 and 42.64 %), respectively in the interaction treatment (V4H0).As mentioned previously, Dakota *var.* surpassed other genotypes of all yield parameters, these results may refer to the greater response of this genotype to humic acid compared than others.

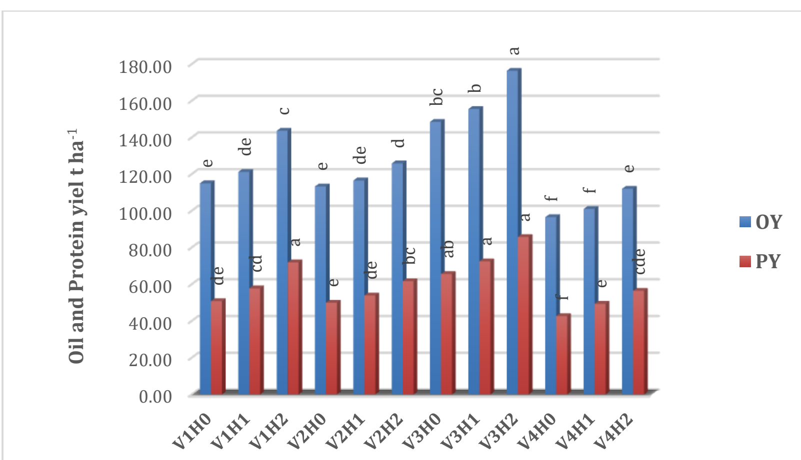

Figure 8. Effect of combination between genotypes and humic acid levels on oil and protein yields (t. ha^{-1}). Means with different letters differ significantly at ($p \leq 0.05$).

3. Fatty acids and chemical components

A. Effect of genotypes and humic acid on palmitic and stearic acids (%):

Any significance was not found between genotypes and also humic acid levels of palmitic and stearic fatty acids (Table 4). Despite that, slight differences were noted when humic acid levels were added to the plants, so the highest values were noted at the level 40 kg. ha^{-1}, were (6.68 and 3.12 %), for (Palmitic and Stearic), respectively, which were greater than outcomes of (H1 and H0), levels. This also true about the interaction effects as can be seen in the (Figure 9). Stearic acid % significantly increased by adding humic acid (Heydari *et al.,* 2021).

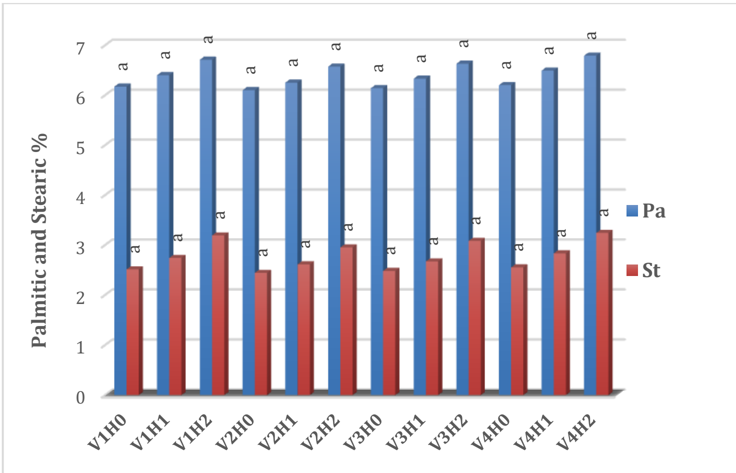

Figure 9. Effect of combination between genotypes and humic acid on palmitic and stearic acids *(%).* Means with different letters differ significantly at ($p \leq 0.01$).

B. Effect of genotypes and humic acid on oleic and linoleic acids (%):

Oleic and linoleic were not changed significantly by the genotypes and also by the humic acid effects except linoleic (Table 4). The highest value of linoleic (Omega-6), was noted by (59.34 %), when 40 kg. ha^{-1} of humic added to the plants. Whereas, 57.64 % was a value of linoleic in the control treatment (H0). Based on the results were found in current study omega-6 was improved, so as known that omega-6 is one of the fatty acids, which plays a crucial role in brain function, and normal growth and development. On the other hand, it is a fact the oleic (a monounsaturated omega-9 fatty acid), was not statistically changed but it was improved by adding humic acid to the sunflower plants, which should be cared for in this case. Since oleic acid has the role of improving heart conditions by lowering cholesterol and decreasing inflammation.

Table 4. Single effect of genotypes and humic acid on fatty acids and chemical parameters.

genotypes	Fatty acids and chemicals (%)						
	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Oil	Protein
HS360 (V1)	6.43[a]	2.18[a]	22.71[a]	58.54[a]	1.27[a]	42.66[a]	20.17[a]
Flamme (V2)	6.31[a]	2.67[a]	22.44[a]	58.19[a]	1.16[a]	42.48[a]	19.73[a]
Dakota (V3)	6.37[a]	2.74[a]	22.57[a]	58.34[a]	1.22[a]	42.63[a]	19.80[a]
Pionner (V4)	6.49[a]	2.87[a]	22.80[a]	58.73[a]	1.34[a]	42.79[a]	20.45[a]
Humic acid							
H0 (control)	6.15[a]	2.50[a]	22.12[a]	57.64[b]	1.04[a]	42.19[c]	18.62[c]
H1 (20 kg ha^{-1})	6.37[a]	2.71[a]	22.57[a]	58.36[ab]	1.20[a]	42.58[b]	20.15[b]
H2 (40 kg ha^{-1})	6.68[a]	3.12[a]	23.21[a]	59.34[a]	1.51[a]	43.15[a]	21.35[a]

*Means with different letters differ significantly at ($p \leq 0.01$), else oil and protein % at ($p \leq 0.05$)

The highest value of oleic acid was recorded when humic added at level of 40 kg. ha^{-1}, which was by (23.21 %).

Figure 10 shows non-significant differences between genotypes and humic acid levels of the same parameters for whole treatments.

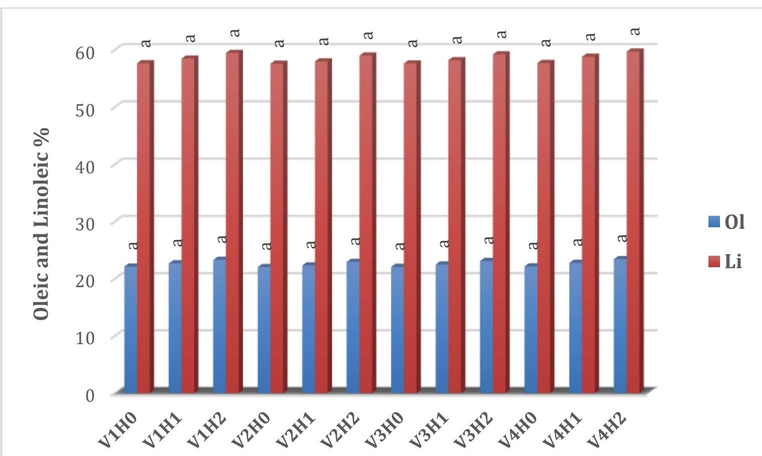

Figure 10. Effect of combination between genotypes and humic acid on oleic and linoleic acids (%). Means with different letters differ significantly at ($p \leq 0.01$).

C. Effect of genotypes and humic acid on linolenic (%):

Any significances were not found by the single and interaction treatments of both factors for linolenic acid (Table 4 and Figure 11).

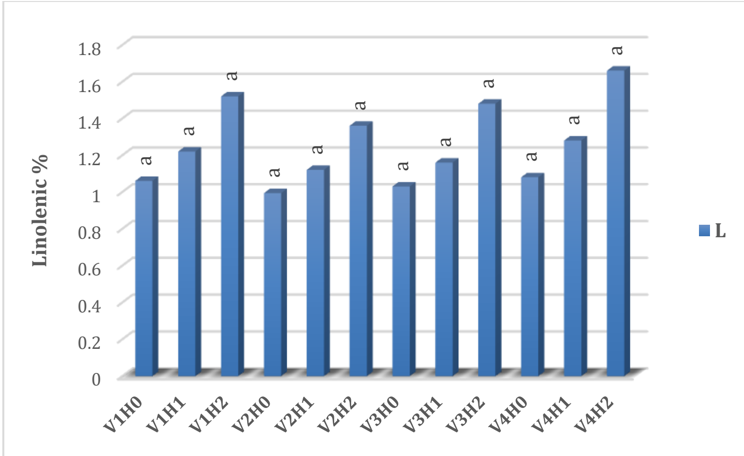

Figure 11. Effect of combination between genotypes and humic acid on linolenic acid (%). Means with different letters differ significantly at ($p \leq 0.01$).

D. Effect of genotypes and humic acid on oil and protein (%):

No significant differences were evident between genotypes in the percentages of oil and protein, while humic acid levels showed significant differences for the two traits. (Table 4). The maximum values were (43.15 and 21.35 %), for oil and protein, respectively when 40 kg. ha^{-1} of humic was used, which were greater than other treatments. These results strongly supported by similar findings were confirmed that humic acid application increased the percentage of oil and protein in seeds of sunflower (Mourad *et al.*, 2021). Also, the fat and protein percentage of kenaf plants were increased when humic acid was applied to the plants at the different levels (Sultan and Salih, 2022).

Any significance was not recorded by the interaction effects of oil percentage, while protein content was significantly changed (Figure 12). The maximum values of protein found in the treatments of (V4H2 and V1H2), by (21.78 and 21.56 %), respectively followed by (V2H2 and V3H2), by (21.05 and 21.00 %), respectively. These results showed that humic acid had the significant role of improving the important chemical substantial in the seeds of sunflower plants such as protein.

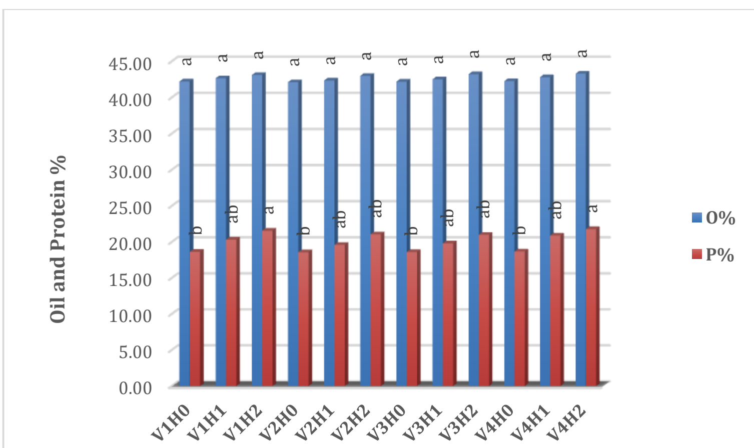

Figure 12. Effect of combination between genotypes and humic acid levels on oil and protein (%). Means with different letters differ significantly at ($p \leq 0.05$).

CONCLUSIONS

From the results of this study it could be concluded that the application of different levels of humic acid (H), to different genotypes of sunflower plants enhanced all growth, yield and yield components characteristics that were taken in this present study. While, any significance was not found in the fatty acids of sunflower seeds except linoleic acid. 40 kg. ha^{-1} of humic acid was the best level for all of the characteristics above. Additionally, growth, yield and yield component characteristics were also significantly changed between genotypes, again fatty acids were not. Finally, it could be concluded also both levels of humic acid (H1 and H2), had impact to improve whole quantity and quality characteristics of sunflower plants. On the other hand, results of yield and yield components showed that Dakota *var.* was better than other genotypes, which may be due to greater ability to uptake humic acid compared to others.

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