International Journal of Sustainable Agriculture 11 (1): 09-18, 2023
ISSN 2079-2107
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DOI: 10.5829/idosi.ijsa.2023.09.18

The Glutamic Acid Spraying Exposes Significant Effect on Yield and Agronomic Characteristics of Sunflower (*Helianthus annuus* L.)

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Abstract: The present study was conducted to determine the effects of glutamic acid treatments at different doses on yield and growth parameters of some sunflower varieties under Anbar-Iraq conditions in 2021. Glutamic acid treatments were practiced as foliar sprays at four different concentrations (0, 100, 200 and 300 mg l^{-1}) to three different sunflower varieties (Sakha, Amar and Ishaqi-1). Field experiments were conducted in randomized blocks split-plots experimental design with three replications. Sunflower varieties were placed into the main plots and glutamic acid concentrations were placed into the sub-plots. The highest average stem height was measured as 194.25 cm, leaf area as 10188.70 cm^2, number of leaves per plant as 23.93 leaf $plant^{-1}$, plant dry weight as 181.22 g, seed weight as 49.17 g $plant^{-1}$, seed yield as 4.87 t ha^{-1} and biological yield as 17.98 t ha^{-1}. The 100 mg l^{-1} glutamic acid treatments of the variety Aqmar yielded the highest head diameter (17.525 cm). The 100 mg l^{-1} glutamic acid treatments of the variety Ishaqi-1 were superior in number of seeds per head (850 seed $plant^{-1}$). The 100 mg l^{-1} glutamic acid treatments of the variety Sakha were superior in 1000-seed weight (66.50 g) and harvest index (33.58 t ha^{-1}). As a result, the highest seed yield (5.49 t ha^{-1}) was obtained with 300 mg l^{-1} glutamic acid treatments in Ishaqi-1 sunflower variety.

Key words: Sunflower · Glutamic Acid · Growth · Yield

INTRODUCTION

Sunflower (*Helianthus annuus* L.), belonging to *Asteraceae* (*Compositae*) family, is one of the most important oil crops in the world and ranks third after soybean and rapeseed in the amount of oil produced at the global level. Sunflower is originated from Mexico in Central America and then moved to European countries, especially to Spain [1].

Sunflower is the first oil crop in Iraq [2]. Iraq is ranked fifth after Morocco, Syria, Egypt and Tunisia in terms of the area planted with the crop in the Middle East. The productivity of this crop in Iraq is still below the required level due to the failure to follow the correct scientific methods and practices in sunflower cultivation. For selecting suitable varieties for specific areas, the scientific experiments were performed by the researcher such as Aljubouri *et al*. [3], Al-Waeli [4], Nasralla *et al* . [5], Al-Ramadan and Al-Abdullah [6], Abdel-Hafeez *et al.* [7] in the similar temperate climate to Anbar.

Glutamic acid is one of the amino acids that make up the proteins of all organisms and one of the most abundant ones in the nature. Glutamic acid belongs to the group of negatively-charged polar amino acids. It was discovered in 1866 by a German chemist Rittershausen while studying hydrolyzed wheat gluten, hence it was named as "glutamic" acid. It has a central role in the synthesis of important proteins and, entering into the composition of chlorophyll leads to an increase in the rate of photosynthesis. The early studies showed that the external amino acid applications, such as “glutamic acid” (activates the biosynthesis of (proline) L-Proline) help some plants to resist most stress conditions such as salinity, cold and high temperatures, as well as drought [8-13].

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Previous studies given some of them following have proven that foliar sprays were an effective to increase yield and formation of agricultural characteristics. Majeed and Al-Bahadli [14] conducted field experiments to study the response of the sunflower spraying of amino acid proline derived from glutamic acid at different concentrations (0, 50 and 100) mg l^{-1} and to different irrigation durations. Results revealed that the highest stem height (126.19 cm), leaf area (0.41 m^2) and seed weights (352.30 - 361.45 kgm^2) were obtained from 100 mg l^{-1}proline concentration. Sarheed *et al.* [15] conducted field experiments on three sunflower cultivars and expressed that study results showed a significant difference in plant growth and yield. The highest plant height, leaf area, head diameter seed yield recorded as 171.53 cm, 4446 cm^2.$plant^{-1}$, 13.76 cm and 3.629 t h^{-1}, respectively. Abass and Alag [16] conducted field experiments on sunflower (*Helianthus annuus* L.) with different irrigation treatments (40%, 50% and 60%) and foliar proline (derived from glutamic acid) sprays at different concentrations (0, 30, 60 and 90 mg l^{-1}) and the highest 100-seed weight (7.52 g - 7.12 g) and seed yield (3.75 t ha^{-1} - 2.21 t ha^{-1}) values were obtained from 60 mg l^{-1} amino acid concentration. Al-Bahadly [17] conducted field experiments to determine the response of sunflower to proline under different irrigation intervals and he recorded that the greatest yield (3.48 t ha^{-1}), number of leaves (28.60), leaf area (2.28 cm^2) and head diameter (17.48 cm) values were obtained from 100 mg l^{-1}proline concentration. Sarwar *et al.* [18] found in a study conducted in Pakistan on several hybrids of sunflower that significant differences between them were seen in 1000-seed weights and it changed between 49.11 and 48.12 g $plant^{-1}$. Al-Janabi and Al-Jebouri [19] conducted field experiments on in two genetic structures of sunflower in two sites and indicated that the average plant heights recorded between 108.62 and 129.18 cm). Tahsin and Yankov [20] reported that according to the result of their study taking part five hibrit varieties (Albena Super Start ZoraSantafe San Luka) in Bulgaria, there were a difference between hibrit varieties in the height of the stems (changed between 151.6 and 167.0 cm), number of leaves per plant (27.6 and 33.2), head diameter (16.3 and 19.0 cm), number of seed per plant (1032.7 and 1652.8 pcs) 1000-seed weight (42.2 and 56.3 g), seed yield (2427 and 3095 kg/ha). Carrillo-Ávila *et al.*[21] worked on several sunflower hybrids (Fullsum, Sunbright, Pradoreshade, CH382) in one of the states of Mexico and indicated that there were significant differences in plant height and the hybrid Fullsum had the highest average plant height of 192.8 cm. Al-Duleimi *et al.* [22] mentioned in a study conducted on different sunflower varieties for two seasons that Shmoos genotype was superior in number of leaves (34.65 and 34.68 leaf $plant^{-1}$) for two seasons, while Flame genotype gave the lowest means for the trait (30.94 and 31.49 leaf $plant^{-1}$) for two seasons, respectively. Al-Salim *et al*. [23] conducted field experiments on two sunflower cultivars (Flammely and Euroflore) in thi-Qar town-Iraq, they reported that the highest seed weight per plant recorded between 40.3 and 44.8 g $plant^{-1}$ changing varieties and plant densities. Flammely variety had higher leaf area (2.087 cm^2). Al-Ramadan and Al-Abdullah [6] conducted a research on four different sunflower cultivars (Urflo, Flame, Velta, As -508) for two seasons and reported significant differences in yield components of the cultivars. In both seasons, the hybrid Urflo had the highest average head diameters (15.2 cm and 15.45 cm) and the highest average number of seeds per head (661.84 seed $plant^{-1}$ and 672.84 seed $plant^{-1}$).

The present study was carried out in a private field in the city of Hit, in Anbar Governorate, western Iraq during the spring season in 2021. In the study, the effects of foliar sprays of glutamic acid at different concentrations (0, 100, 200, 300 mg l^{-1}) on yield and agronomic properties of three sunflower cultivars (Sakha, Aqmar, Ishaqi-1) were investigated.

MATERIALS AND METHODS

The present study was carried out in a private field in the city of Hit, in Anbar Governorate, western Iraq during the spring season in 2021. Effects of foliar sprays of glutamic acid at different concentrations Glu 0, Glu 100, Glu 200 and Glu 300 (0, 100, 200, 300 mg l^{-1}, respectively) on yield and growth parameters of three sunflower cultivars (Sakha, Aqmar, Ishaqi-1) were investigated.

The experiments were conducted in randomized blocks split-plots experimental design with three replications. Glutamic acid concentrations were placed into the sub-plots and sunflower cultivars were placed into the main plots. Experimental plots were 3.50 m long and 2.80 m wide (9.8 m2). Sowing was performed on 3/08/2021 at 0.70 m row spacing and 0.25 m on-row plant spacing. Weed control, fertilizer and irrigation practices were performed properly during the growing season. Glutamic acid foliar sprays were performed in two growth stages of plants: the first one at the beginning of plant growth seedling stage and the second one at the beginning of head formation stage.

In the experiment, measured characteristics were vegetative growth parameters (stem height, number of leaves per plant, leaf area, head diameter) and yield and yield components (number of seeds per head, seed weight per plant, 1000-seed weight, biological yield, seed yield and harvest index). They were measured in accordance with the previous studies Aljubouri *et al*. [3], Sarheed *et al*. [15], Al-Janabi and Al-Jebouri [19] and Al-Salim *et al*. [23].

To determine significance of difference between treatments, Variance analysis (ANOVA) was performed and, Duncan's Multiple Range Test (MRT) was used to compare the means by using MSTAT-C software package [24].

RESULTS AND DISCUSSION

Vegetative Growth Parameters

Stem Height (cm): According to results of the study, the averages of stem height of the varieties changed between 181.37 - 194.25 cm with the highest value (199.80 cm) from Glu 300 (300 mg l^{-1}) treatment of Ishaqi-1 and the lowest value (163.47 cm) from the control Glu 0 treatment of the same variety (Table 1). Stem heights varied with treatments of different glutamic acid concentrations. The greatest value (198.44 cm) was obtained from Glu 300 (300 mg l^{-1}) treatments and the lowest value (179.84 cm) was obtained from the control (Glu 0) treatments.

Number of Leaves per Plant (Leaf $plant^{-1}$): The result of this study revealed that there were significant differences in number of leaves per plant with treatments of different glutamic acid concentrations ($P \leq 0.05$). But, differences between the sunflower varieties were insignificant in terms of number of leaves per plant. Differences in number of leaves per plant of the varieties were not found to be significant (Table 1). The greatest value (23.93 leaf $plant^{-1}$) was obtained from the variety Aqmar and the lowest value (23.52 leaf.$plant^{-1}$) was obtained from the variety V3 (Ishaqi-1). There were significant differences in number of leaves per plant of the interactions. The greatest value (24.33 leaf $plant^{-1}$) was obtained from Glu 300 (300 mg l^{-1}) treatments of the variety Aqmar and the lowest value (22.93 leaf $plant^{-1}$) was obtained from Glu 0 (Control) treatments of the variety V3 (Ishaqi-1). There were no significant differences in number of leaves per plant of glutamic acid concentrations. The highest value (24.04 leaf $plant^{-1}$) was obtained from the Glu 300 (300 mg l^{-1}) treatments and the lowest value (23.22 leaf $plant^{-1}$) was obtained from Glu 0 (Control) treatments.

Leaf Area (cm^2): The results of the analysis of variance for leaf area showed that the significant differences were observed in leaf areas of the experimental treatments of different glutamic acid concentrations and sunflower varieties at $P \leq 0.05$ level. Table 1. shows that the average leaf areas of the varieties changed between 10188.70 cm^2 -

Table 1: Vegatative growth characteristics of the sunflower cultivars subjected to external glutamic acid treatments

	Glutamic Acid Concentrations (mg l^{-1})				
Varieties	Glu 0	Glu 100	Glu 200	Glu 300	Means of Varieties
			Stem height (cm)		
Sakha	183.33e	188.40d	185.07e	198.80a	188.90b
Aqmar	192.73c	193.80c	193.73c	196.73b	194.25a
Ishaqi-1	163.47g	188.27d	173.93f	199.80a	181.37c
Means of Glu	179.84d	190.16b	184.24c	198.44a	
			Number of leaves per plant (leaf $plant^{-1}$)		
Sakha	23.13cd	23.60bc	23.73abc	24.07ab	23.63a
Aqmar	23.60bc	23.80ab	24.00ab	24.33a	23.93a
Ishaqi-1	22.93d	23.93ab	23.47bcd	23.73abc	23.52a
Means of Glu	23.22b	23.78a	23.73a	24.04a	
			Leaf area (cm^2)		
Sakha	7998.00i	8334.67h	9185.93f	9871.67cd	8847.57c
Aqmar	9637.93de	10957.33a	10181.40c	9978.13c	10188.70a
Ishaqi-1	8627.20gh	8716.40g	9491.13fe	10514.60b	9337.33b
Means of Glu	8754.38d	9336.13c	9619.49b	10121.47a	
			Head diameter (cm)		
Sakha	16.57d	17.40bc	18.03ab	17.50bc	17.38a
Aqmar	16.53d	18.57a	17.43bc	17.57bc	17.53a
Ishaqi-1	16.33d	17.87ab	16.97cd	17.93ab	17.28a
Means of Glu	16.48c	17.94a	17.48b	17.67ab	

Means with the same letter are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test.

Table 2: The yield components of the sunflower cultivars subjected to external glutamic acid treatments

Varieties	Glutamic Acid Concentrations (mg l^{-1}) Glu 0	Glu 100	Glu 200	Glu 300	Means of Varieties
		Number of seeds per head (seed $head^{-1}$)			
Sakha	675.33f	898.33ab	826.33cd	878.67abc	819.67a
Aqmar	762.00e	912.33a	812.00de	848.67bcd	833.75a
Ishaqi-1	695.33f	914.67a	869.00abc	924.33a	850.83a
Means of Glu	710.89c	908.44a	835.78b	883.89a	
		Seed weight (g $plant^{-1}$)			
Sakha	33.00g	54.33ab	54.00ab	53.67abc	48.75a
Aqmar	39.67f	53.33bc	51.33cde	52.33bcd	49.17a
Ishaqi-1	35.00g	49.67e	50.67de	56.00a	47.83a
Means of Glu	35.89c	52.44b	52.00b	54.00a	
		1000-seed weight (g)			
Sakha	64.67b	66.67ab	66.67ab	68.00ab	66.50a
Aqmar	55.00c	69.67a	70.67a	66.67ab	65.50a
Ishaqi-1	57.67c	70.00a	68.67ab	68.00ab	66.08a
Means of Glu	59.11b	68.78a	68.67a	67.56a	

Means withthe same letter are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test.

8847.57 cm^2 with the highest value (10957.33 cm^2) from the Glu 100 (100 mg l^{-1}) treatments of Aqmar and the lowest value (7998.00 cm^2) from the Glu 0 (Control) treatments of Sakha. For leaf areas at different glutamic acid concentrations, Glu 300 (300 mg l^{-1}) treatments yielded a higher average of leaf area (10121.47 cm^2) than the Glu 0 (Control) treatments (8754.38 cm^2.

Head Diameter (cm): Table 1 shows the results of the analysis of variance for head diameters. There were significant differences in head diameters depend on the treatments of different glutamic acid concentration and sunflower varieties at $P \leq 0.05$ level. There were no significant differences in head diameters of the sunflower varieties (Table 1). The highest value (17.525 cm) was obtained from the variety Aqmar and the lowest value (17.275 cm) was obtained from the variety Ishaqi-1. Interactions had significant effects on head diameters. The highest value (18.567 cm) was obtained from Glu 100 (100 mg l^{-1}) treatments of the variety Aqmar and the lowest value (16.333 cm) was obtained from Glu 0 (Control) treatments of the variety V3 (Ishaqi-1). There are significant differences in head diameters of glutamic acid concentrations. The greatest value (17.944 cm) was obtained from the Glu 100 (100 mg l^{-1}) treatments and the lowest value (16.478 cm) was obtained from the Glu 0 (Control) treatments. There were no significant differences between Glu 200 and Glu 300 concentrations.

Components of Seed Yield

Number of Seeds per Head (Seed $head^{-1}$): Table 2 shows that there were significant differences in number of seeds per head with the treatments of different glutamic acid concentrations and sunflower varieties at $P \leq 0.05$ level. There were no significant differences in number of seed per head of the sunflower varieties (Table 2). The highest value (850.83 seeds $head^{-1}$) was obtained from the variety Ishaqi-1 and the lowest value (819.67 seed $head^{-1}$) was obtained from the variety Sakha. In terms of the number of seeds per head of interactions, the highest value (924.33 seed $head^{-1}$) was obtained from Glu 300 (300 mg l^{-1}) treatments of the variety Ishaqi-1 and the lowest value (675.33 seed $head^{-1}$) was obtained from Glu 0 (control) treatments of the variety Sakha. For the number of seeds per head of glutamic acid concentrations, the highest value (908.44 seed $head^{-1}$) was obtained from Glu 100 (100 mg l^{-1}) treatments and the lowest value (710.89 seed $head^{-1}$) was obtained from the Glu 0 (control) treatments. There was no significant difference between Glu 100 and Glu 300 concentrations.

Seed Weight (g $plant^{-1}$): According to the result of the present study, there were significant differences in seed weights with the treatments of different glutamic acid concentrations and sunflower varieties at $P \leq 0.05$ level. There were no significant differences in seed weights of the sunflower varieties (Table 2). The highest value (49.17 g $plant^{-1}$) was obtained from the variety Aqmar and the lowest value (47.83 g $plant^{-1}$) was obtained from the variety Ishaqi-1. There were significant differences in seed weights of interactions. The highest value (56.00 g $plant^{-1}$) was obtained from Glu 300 (300 mg l^{-1}) treatments of the variety V3 (Ishaqi-1) and the lowest value (33.00 g $plant^{-1}$) was obtained from Glu 0 (Control) treatments of the variety Sakha. There were significant differences in seed yields of glutamic acid concentrations. The greatest

Table 3: The yield properties of the sunflower cultivars subjected to external glutamic acid treatments

Varieties	Glutamic Acid Concentrations (mg l^{-1}) Glu 0	Glu 100	Glu 200	Glu 300	Means of Varieties
			Seed yield (t ha^{-1})		
Sakha	3.23f	5.33ab	5.30ab	5.26ab	4.78a
Aqmar	3.91e	5.23ab	5.19bc	5.13bc	4.87a
Ishaqi-1	3.43f	4.86d	4.97cd	5.49a	4.69a
Means of Glu	3.53c	5.14b	5.15b	5.29a	
			Biological yield (t ha^{-1})		
Sakha	12.66g	14.09e	13.72ef	16.46c	14.23c
Aqmar	15.12d	18.72ab	18.98ab	19.08a	17.98a
Ishaqi-1	13.30fg	13.71ef	15.53d	18.33b	15.22b
Means of Glu	13.69d	15.51c	16.07b	17.96a	
			Harvest index (%)		
Sakha	25.59f	37.91a	38.73a	32.08c	33.58a
Aqmar	26.10f	27.34ef	28.88de	26.81f	27.28c
Ishaqi-1	25.74f	35.50b	32.89c	29.97d	31.03b
Means of Glu	25.81c	33.59a	33.50a	29.62b	

Means withthe same letter are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test.

value (54.00 g $plant^{-1}$) was obtained from Glu 300 (300 mg l^{-1}) treatments and the lowest value (35.89 g $plant^{-1}$) was obtained from Glu 0 (control) treatments. There was no significant difference between Glu 100 and Glu 200 concentrations.

1000-Seed Weight (g): The result of the present study shows that the significant differences appeared in 1000-seed weights with the treatments of different glutamic acid concentrations and sunflower varieties at $P \leq 0.05$ level. But, there were no significant differences between the varieties in terms of 1000-seed weights (Table 2). The highest value (66.50 g) was obtained from the variety Sakha and the lowest value (65.50 g) was obtained from the variety Aqmar. Interactions had significant effects on 1000-seed weights. The highest value (70.67 g) was obtained from Glu 200 (200 mg l^{-1}) treatments of the variety Aqmar and the lowest value (55.00 g) was obtained from Glu 0(Control) treatments of the same variety. There were significant differences in 1000-seed weights of glutamic acid concentrations. The greatest value (68.78 g) was obtained from the Glu 100 (100 mg l^{-1}) treatments and the lowest value (59.11 g) was obtained from the Glu 0 (control) treatments. There were no significant differences between Glu 200 and Glu 300 treatments.

Yield

Seed Yield (t ha^{-1}): According to the result of the present study, the significant differences were observed in seed yields with the treatments of different glutamic acid concentrations on sunflower varieties at $P \leq 0.05$ level. However, there were no significant differences in seed yields of the sunflower varieties (Table 3). Taken consideration average of varieties in seed yiled, the highest value (4.87 t ha^{-1}) was obtained from the variety Aqmar and the lowest value (4.69 t ha^{-1}) was obtained from the variety Ishaqi-1. There were significant differences in seed yields with treatment of different glutamic acid concentrations. The highest value (5.29 t ha^{-1}) was obtained from Glu 300 (300 mg l^{-1}) treatments and the lowest value (3.53 t ha^{-1}) was obtained from Glu 0 (control) treatments. There were no significant differences in seed yields of Glu 100 and Glu 200 treatments. As seen on the Table 3, the interactions of glutamic acid treatments and sufflower varieties had significant effects on seed yields. The highest value (5.49 t ha^{-1}) was obtained from Glu 300 (300 mg l^{-1}) treatments of the variety Ishaqi-1 and the lowest value (3.23 t ha^{-1}) was obtained from Glu 0 (control) treatments of the variety Sakha.

Biological Yield (t ha^{-1}): The result of the present study shows that there were significant differences in biological yields of the experimental treatments (glutamic acid concentrations and sunflower varieties) at $P \leq 0.05$ level. For biological yields of the varieties, the highest value (17.98 t ha^{-1}) was obtained from the variety Aqmar and the lowest value (14.23 t ha^{-1}) was obtained from the variety Sakha (Table 3). There were significant differences in biological yields of the interactions. The greatest value (19.08 t ha^{-1}) was obtained from Glu 300 (300 mg l^{-1}) treatments of the variety Aqmar and the lowest value (12.66 t ha^{-1}) was obtained from Glu 0 (control) treatments

of the variety Sakha. In terms of biological yields, the highest value (17.96 t ha^{-1}) was obtained from the Glu 300 (300 mg l^{-1}) treatments and the lowest value (13.69 t ha^{-1}) was obtained from the Glu 0 (control) treatments.

Harvest index (%): There were significant differences in harvest index values of the experimental treatments (glutamic acid concentrations and sunflower varieties) at $P \leq 0.05$ level according to result of this study. It can be seen Table 3 that the highest value (33.58%) was obtained from the variety Sakha and the lowest value (27.28%) was obtained from the variety Aqmar in terms of harvest index of sunflower varieties. There were significant differences in harvest index values of the interactions. The highest value (38.73%) was obtained from Glu 200 (200 mg l^{-1}) treatments of the variety Sakha and the lowest value (25.59%) was obtained from Glu 0 (Control) treatments of the same variety. In terms of harvest index values of different glutamic concentrations, the highest value (33.59%) was obtained from the Glu 100 (100 mg l^{-1}) treatments and the lowest value (25.81%) was obtained from the Glu 0 (Control) treatments. There were no significant differences between Glu 100 and Glu 200 treatments.

DISCUSSION

Vegetative Growth Parameters

Stem Height (cm): In the present study, the stem heights varied with the experimental treatments (glutamic acid concentrations and sunflower varieties). There were significant differences in stem heights of the varieties with the greatest value from the variety Aqmar. Stem heights increased with increasing glutamic acid concentrations. Atiyah and Kadhim [2] also indicated significant effects of environmental factors and agronomic practices on growth parameters of sunflower plants. There were also significant differences in stem heights obtained at different glutamic acid concentrations with the greatest value from Glu 300 (300 mg l^{-1}) treatments. Hamed [25] applied foliar sprays of salicylic acid to sunflower plants and reported that salicylic acid treatments increased the cell growth rates through the accumulation of metabolic products in developing parts, improved carbon efficiency and concentration of hormones such as auxins, glibrinates and kinetin. Majeed and Al-Bahadli [14] reported that amino acid sprays encouraged vital activities, thus stimulated longitudinal growth of sunflower plants. Present findings on stem heights comply with those earlier ones.

Number of Leaves per Plant (Leaf $plant^{-1}$): According to result of the present study, the statistical analyses revealed that there were no significant differences in number of leaves per plant of the sunflower varieties, probably because the genetic structures of the varieties had the same effect on number of leaves per plant trait of the varieties. However, there were significant differences in number of leaves per plant values obtained at different glutamic acid concentrations. Amino acids activate many important hormones, such as auxin, cytokinin and ABA hormone with an important role in the processes of vegetative growth [14]. Complying with the present findings on number of leaves per plant, Al-Kaisi *et al*. [26] reported significant positive effects of citric and glutamic acid treatments on number of leaves per plant of the bean plants since glutamic acid had the ability to secrete substances similar to plant hormones and nutrients.

Leaf Area (cm^2): There were significant differences in leaf areas of the sunflower varieties mostly because of genetic structures of the varieties according to result of the present study. Genetic capabilities and acidic nature of nutrients required for plant growth and development reflected as an increase in leaf area [2]. Consistent with the present findings, Kalaf and Mahidi [27] reported significant increases in leaf areas with amino acid treatments. Ghassemi-Golezani *et al*. [28] reported a significant increase in leaf area of soybean plant with salicylic and jasmonic acid treatments.

Head Diameter (cm): The statistical analysis revealed that there were no significant differences in head diameters of the sunflower varieties, but significant differences were seen in head diameters obtained at different glutamic acid concentrations. Majeed and Al-Bahadli [14] indicated sunflower crop response to proline treatments during different irrigation periods. Present findings on head diameters are consistent with the findings of Abass and Alag [16] indicating the role of proline in improving the yield and yield components of sunflower under water stress conditions.

Components of Seed Yield

Number of Seeds per Head (Seed $head^{-1}$): The statistical analyses of the present study data revealed that there were significant differences in number of seeds per head of the sunflower varieties. The variety Ishaqi-1 outperformed the rest of the varieties and the reason is the correlation of the result of the number of seeds per head, which caused an increase in the number of total seeds per head.

Seed Weight (g plant^{-1}): The present study findings indicated that there were significant differences in seed weights of the sunflower varieties. The reason may be due to disturbances in mineral absorption and promotion of plant respiration, in addition to the difference in genetic characteristics. Consistent with the present findings on seed weights, Sadak and Mostafa [29]. There were also significant differences in seed weights obtained at different glutamic acid concentrations since amino acids acted as a catalyst. Glutamic acid protects the plant from stressful conditions due to its osmotic effect on the mechanism of photosynthesis and regulation of ionic balance, as well as improving carbon dioxide uptake under environmental stresses [30]. Present findings were consistent with the results of Majeed and Al-Bahadli [14] indicating significant effects of proline treatments on growth parameters of the sunflower plants.

1000-seed Weight (g): The data of statistical analyses from the present study result revealed that there were no significant differences in 1000-seed weights of the sunflower varieties, but there were significant differences in 1000-seed weights obtained at different glutamic acid concentrations. Increasing 1000-seed weights were observed with increasing glutamic acid concentrations, since glutamic acid treatments increased vital activities and accelerated cell division and expansion, thus increased average yields. Majeed and Al-Bahadli [14] reported significant effects of proline treatments on seed yields and 1000-seed weights. Abass and Alag [16] also reported significant effects of proline treatments on yield components of sunflower plants including 1000-seed weights. Amino acids have an effective role in regulation of osmosis inside the cell and maintaining the relative water content of the leaves, which led to increase of seed weights [30].

Yield

Seed Yield (t ha^{-1}): The seed yield data indicated that there were significant differences in seed yields of the sunflower varieties and the variety Aqmar was superior in seed yield because of superiority of the variety in the other growth indicators related to seed yield [30]. There were also significant differences in seed yields obtained at different glutamic acid concentrations. External application of amino acids has a role in regulating leaf osmosis and drawing water from the neighboring plant cells and maintaining the fullness of cells. External amino acid treatments also play an important role in cell cleavages, number of cells and prevention of amino acid oxidation [25]. Present findings on seed yields were consistent with the results of Khan *et al*. [31] indicating an important role of salicylic acid in bearing abiotic stresses in plants. Memon *et al.* [32] declared that sunflower hybrids showed diverse growth and seed yield performance according to result of their study in Pakistan.

Biological Yield (t ha^{-1}): The statistical analyses of data from the present study revealed that there were significant differences in biological yield of the sunflower varieties and variety Aqmar with superior vegetative growth parameters such as stem height and number of leaves outperformed the rest of the other varieties since the number of leaves per plant then reflected as an increase in the biological yield [30]. There were significant differences also in biological yields obtained at different glutamic acid concentrations. Present findings on biological yields are consistent with the findings of Abass and Alag [16] indicating the role of proline in improving yield and yield components of sunflower plants under stress conditions. The reason for the increase in seed yield with increasing proline concentrations is due to its important role in improving the hormonal balance, which helps to stimulate buds, regulate flowering and stabilize the fruit set, which in turn positively reflected on productivity of seeds per unit area [31]. Present findings of biological yields are also consistent with the findings of Majeed and Al-Bahadli [14] indicating positive effects of proline treatments on biological yields of sunflower (*Helianthus annuus* L.) plants.

Harvest Index (%): Present findings revealed that there were significant differences in harvest index values of the sunflower varieties. The reason for this may be the transfer of nutrients from the source to the estuary, which is the upper part of the plant, specifically the seeds, which increases its growth and collection and thus increases the average 1000-seed weight, which is then reflected in increased quality of the harvest index. There were no significant differences in harvest index values obtained at different glutamic acid concentrations due to the role of amino acids in the hormonal balance and the increase in the level of cytokinin hormone inside the plant and its contribution to increasing the proportion of the flowering hormone (fluorogen) as it controls the emergence, differentiation and growth of the flowers [25].

CONCLUSION

The result of present study indicated that there were significant differences in seed yields of the sunflower varieties and the variety Aqmar was superior in seed yield as becoming superior variety in the other growth indicators related to seed yield. There were also significant differences in seed yields obtained at different glutamic acid concentrations. The external application of glutamic acid increased the seed yield, in general. In term of biological yields, both varieties and glutamic acid treatments had significant effects. The increment of glutamic acid concentrations resulted gradual increasing in the biological yields.

The increasing 1000-seed weights were observed with increasing concentrations of glutamic acid application. There were no significant differences in harvest index values obtained of application of the different glutamic acid concentrations, but there were in terms of varieties.

As a conclusion, the suitable and adaptable varieties are to be selected for specific distinct for enable high yield and quality form sunflower plant. Also, the external glutamic acid treatments could have positive effects on yield and yield parameters of sunflower.

ACKNOWLEDGEMENT

This article was derived from Master Thesis of Mr. Riyadh Taha DWAYYEH approved with 08 February 2022 date and 2022/08.02 numbered decision of Department of Agricultural Science and Technologies, Graduate School of Natural and Applied Sciences, Erciyes University. This article is dedicated to the memory of Riyadh Taha Dwayyeh.

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