Original Research Article

The external glutamic acid application results in significant effects on some characteristics of sunflower (*Helianthus annuus* L.)

Riyadh Taha DWAYYEH [1], Ali Irfan ILBAS [2,*], Muaiad Hadi Al-Ani [3]

Abstract

The present study was conducted to determine the effects of glutamic acid treatments at different doses on determined characteristics of some sunflower varieties. 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 in a split-plot experimental design with three replications under Anbar-Iraq conditions in 2021. The highest average leaf area index was 5.82 cm^2. The 100 mg l^{-1} glutamic acid treatments of the variety Aqmar yielded the highest chlorophyll content (40.51%). For the variety Ishaqi-1, the 100 mg l^{-1} glutamic acid treatment resulted in the highest protein content (15.51%). However, the 200 mg l^{-1} glutamic acid treatments of the variety Ishaqi-1 resulted in an increase in empty seeds rate (75.29%) and oil content (44.09%). In general, medium external glutamic acid doses (100 mg l^{-1} and 200 mg l^{-1}) increase the chlorophyll content and protein content, and oil content, respectively. But, the empty seed rate also increased with 200 mg l^{-1} application.

Keywords

Sunflower, Amino Acids, Glutamic Acid, Oil Content, Protein Content, Leaf Area Index, Chlorophyll Content, Empty Seed Rate

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Aplikacija glutaminske kisline pomembno vpliva na nekatere lastnosti sončnice *Helianthus annuus*

Izvleček

V pričujoči študiji smo ugotavljali učinke tretiranja z glutaminsko kislino v različnih odmerkih na določene lastnosti nekaterih sort sončnic. Tretiranje z glutaminsko kislino je bilo izvedeno kot listno škropljenje v štirih različnih koncentracijah (0, 100, 200 in 300 mg l^{-1}) na treh različnih sortah sončnic (Sakha, Amar in Ishaqi-1). Poljski poskusi so bili izvedeni v randomiziranih blokih v poskusni zasnovi z razdeljenimi ploskvami s tremi ponovitvami na območju Anbar-Irak (leto 2021). Najvišje povprečje indeksa listne površine je bilo 5,82 cm^2. Po tretiranju z 100 mg l^{-1} glutaminske kisline pri sorti Aqmar smo določili najvišjo vsebnost klorofila (40,51 %). Pri sorti Ishaqi-1 smo po obdelavi z 100 mg l^{-1} glutaminske kisline določili najvišjo vsebnost beljakovin (15,51 %). Vendar se je pri obdelavi z 200 mg l^{-1} glutaminske kisline pri sorti Ishaqi-1 povečala stopnja praznih semen (75,29 %) in vsebnost olja (44,09 %). Na splošno lahko zaključimo, da srednji odmerki glutaminske kisline (100 mg l^{-1} in 200 mg l^{-1}) povečajo vsebnost klorofila in beljakovin ter vsebnost olja. Pri uporabi 200 mg l^{-1} pa se poveča tudi delež praznih semen.

Ključne besede

Sončnica, aminokisline, glutaminska kislina, vsebnost olja, vsebnost beljakovin, indeks listne površine, vsebnost klorofila, delež praznih semen

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 originated from Mexico in Central America and then moved to European countries, especially to Spain (Al-Fahaadi, 2012).

The importance of the sunflower crop comes from the fact that its seeds contain a high percentage of oil that reaches nearly 50% of seed mass in some of the improved varieties, therefore providing the largest amount of oil per unit of cultivated area, in addition to good taste characteristics of the oil (Khalaf and Rahman, 2015). Since seed oil of this crop is characterized by its good taste, it is widely used in the manufacture of high nutritional oils, manufacture of butter, bread and biscuit products. It is also used in the manufacture of soap and gums. According to results of the study of Vasudha and Sarla (2021), sunflower seed cake contains 37.10% crude protein and 250.56 kcal energy per 100g, therefore, it is also a good sources of fodder for farm animals. Gul and Coban (2020) recorded that the oil contents of ten varieties in two different locations varied from 36.47 to 50.29%. Radić et al. (2009) reported that oil contents and protein contents varied between 31.34-48.90% and 15.07-26.74% for two genotypes and two locations, respectively expressed depend on result of their study with tow genotypes in two locations.

Recently, the importance of this oil crop has increased as a result of the shortage in the produced quantity of oils in the world. In the Middle East, sunflower is the third most important oil seed crop after soybean and palm oil (Al-Amery et al., 2011). Currently, it ranks second in terms of production after soybean and first in oil production in Iraq (Al-Rawi and Kavanagh, 1998). Sunflower is the first oil crop in Iraq (Ali Atiyah and Hasson Kadhim, 2019). Iraq is ranked fifth after Morocco, Syria, Egypt, and Tunisia in terms of the area planted with this crop in the Middle East (Nasralla et al., 2014). 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.

Breeding and introduction of new varieties of sunflower in Iraq are needed to test them in terms of biological and agronomic characteristics and quality in Iraq and anywhere exposed to these new varieties. In the view of selecting suitable varieties for specific areas, scientific experiments were performed among others by Hamza et al. (2011),

Nasralla et al. (2014), Al-Waeli et al. (2018), Abdel-Hafeez et al. (2019), Aljubouri et al. (2019), Al-Ramadan et al. (2021) in a similar temperate climate to Anbar. The difference in characteristics of the sunflower genotypes mostly comes from the difference in the physiological processes of these genotypes after flowering (de la Vega and Hall, 2002). Several studies have been conducted to compare different genotypes of sunflower, most of which indicated that the characteristics of sunflower could differ between varieties and according to climatic conditions, where they are grown (Kaya et al., 2007; Ayad et al., 2010; Dutta et al., 2011; Kaleem et al., 2011; Sarwar et al., 2013).

Amino acids, especially glutamic acid and glycine, enter the formation of the chlorophyll molecule and their use increased the rate of photosynthesis in plants. Amino acids and their activities in different plant growth stages increase the ability of the cell to absorb water and dissolved nutrients from the growth medium and thus increase vegetative growth. Amino acids increase protein synthesis and are involved in several plant functions, enhance metabolism and the rate of carbon uptake and increase total dry matter (Sharma-Natu and Ghildiyal, 2005; Dromantiene et al., 2013).

Glutamic acid is one of the amino acids that make up the proteins of all organisms and one of the most abundant ones in nature. Since organisms have intrinsic pathways for their biosynthesis, it is not considered essential (Forde and Lea, 2007). 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 "glutamic" acid. After the discovery, its presence was determined in a large part of living organisms, which is why, it is believed to have essential functions for life. It has a central role in the balance between carbon and nitrogen within the plant, as well as the synthesis of important proteins. It enters the synthesis of chlorophyll, which leads to an increase in the rate of photosynthesis. Glutamic acid is an α-amino acid that has a central carbon atom, the α-carbon, to which four other groups are attached: a carboxyl group, an amino group, a hydrogen atom and a substituent group (side chain or R group). The R-group of glutamic acid gives the molecule a second carboxyl group (-COOH) and its structure -CH2-CH2-COOH (-CH2-CH2-COO-in its ionized form), so the sum of the carbon atoms of the molecule is five. Glutamic acid releases special signals for growth. It plays an important role in balancing nutrients through plant tissues and increases the consumption and absorption of elements in addition to making up carbohydrates and proteins in the plant and improving physiological characteristics (Forde and Lea, 2007). The amino acid “glutamic acid”, which is in the free state in the form of L-Glutamic, activates the biosynthesis of (proline) L-Proline, which is one of the most important amino acids that help plants to resist most stress conditions such as salinity, cold and high temperatures, as well as drought (Farid et al., 2020).

Previous studies have proven that foliar sprays were effective in increasing some biological and agricultural characteristics.Alak (2016) conducted field experiments on the sunflower (*Helianthus annuus* L.) cultivar Luleo for two seasons to examine the phenotypic characteristics, yield and growth parameters under 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}). Amino acid concentrations had significant effects on most of the studied traits. In both seasons, the greatest percentage of fertility (70.20% – 81.45%) was obtained from 60 mg l^{-1} amino acid concentration.

Majid and Al-Bahadli (2016) conducted field experiments to study the response of the sunflower (*Helianthus annuus* L.) cultivar Flame to sprays 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 amino acid concentration × irrigation duration interactions had significant effects on most of the studied traits. The highest average leaf area (0.41 m^2) was obtained from 100 mg l^{-1} proline concentration. They noted that seed oil contents also increased with increasing amino acid concentrations. Dahi et al. (2015) conducted field experiments in Baghdad during the spring season of 2013 to study the effects of different water stress levels (20%, 50% and 80%), different proline concentrations (0, 150 and 300 mg l^{-1}) and salicylic acid concentrations (0, 200, and 400 mg l^{-1}) on yield and growth parameters of Shmoos sunflower variety. The results of the study showed that 200 mg l^{-1} salicylic acid concentration was the most effective and yielded an average leaf area of 0.3494 m^2, and a total chlorophyll content of 0.802%. Mahdi et al. (2009) indicated in a study of two sunflower cultivars (Aqmar and Brodeferic) that the Aqmar cultivar was significantly superior in oil content, as it recorded the highest mean for oil content (47.68%), while the cultivar Brodeferic recorded the lowest mean value (45.18%).

The present experimental study was conducted to

determine the effects of foliar glutamic acid treatments externally at different concentrations on various biological and agronomical traits of different sunflower varieties in Anbar district of Iraq, which are characterized by high temperatures throughout the growing season.

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 (0, 100, 200, 300 mg l^{-1}) on yield and growth parameters of three sunflower cultivars (Sakha, Aqmar, Ishaqi-1) were investigated.

The experiments were conducted in randomized blocks in a split-plot experimental design with three replications. Glutamic acid concentrations coded Glu-0, Glu-100, Glu-200 and Glu-300 (0, 100, 200, 300 mg l^{-1}, respectively) were applied in 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 m^2). Sowing was performed on 3/08/2021 at 0.70 m row spacing and 0.25 m on-row plant spacing. Weed control was done by hoeing and weeding. Pre-sowing period, diammonium phosphate (DAP, 18-46-0 % NPK) fertilizer was applied by calculating of 200 kg ha^{-1}. When plants reached 25-30 cm height 150 kg ha^{-1} urea (48% N) applied as a second batch of nitrogen fertilizer. During the growing season, five times irrigation was performed at 70-100 mm in each time when plants needed by the basin irrigation system. 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 the head formation stage.

Measured characteristics were leaf area index, chlorophyll content, empty seed rate, oil content, and protein content. Leaf area index was calculated with the use of the following equation: Leaf area index = Average leaf area of per plant / the area that a plant occupies on the ground. Leaf chlorophyll content (%) was determined by using A SPAD meter (SPAD 502) by performing five readings on middle leaves. To determine the empty seed rate (%), about 50 g of seeds were taken from each plot, then the number of empty and filled seeds were counted. And, empty seed rate was calculated as: number of empty seeds / total number of seeds × 100. To determine oil content, seeds were ground and placed into a beaker, then supplemented with ethanol and placed into hexane-supplemented Soxhlet extraction device at 37°C for 12 hours (Chapman and Pratt, 1961). The following equation was used to calculate the oil content of the samples: Percentage of oil = Weight of oil extracted from seeds / weight of sample seeds × 100. To determine protein content, initially, sample total nitrogen (N) content was determined with the use of micro-kjeldahl method. The resulting N content was then multiplied by a coefficient of 25.6 to get protein content of the samples. And, used the formula: protein content = Total N × 25.6.

ANOVA, Variance and Standard Error analyses were used to determine the significance of differences and comparing means of treatments by using MSTAT-C software package (Freed et al.,1989).

Results and Discussion

Leaf Area Index (cm^2)

There were significant differences in leaf area values of the sunflower varieties (Table 1). The highest value (5.82 cm^2) was obtained from the variety Aqmar and the lowest value (5.06 cm^2) was obtained from the variety Sakha. In terms of leaf area index values of concentration × variety interactions, the highest value (6.26 cm^2) was obtained from Glu-100 (100 mg l^{-1}) treatments of the variety Aqmar and the lowest value (4.57 cm^2) was obtained from Glu-0 (control) treatments of the variety Sakha.

For leaf area index values at different glutamic acid concentrations, the highest value (5.78 cm^2) was obtained from Glu-300 (300 mg l^{-1}) and the lowest value (5.00 cm^2) was obtained from the Glu-0 (Control) treatments.

Present findings revealed that there were significant differences in leaf area index values of the sunflower varieties, probably because of the genetic structures of the varieties. Adeem (2015) also reported different leaf areas and thus leaf area index values for different sunflower varieties. Abdel Latef and Tran (2016) reported that amino acid treatments had significant effects on the growth parameters of maize plants, increased the production of soluble proteins, total free amino acids and proline, thus improving plant growth through enhancing photosynthetic activity and antioxidant mechanisms. There were significant differences in leaf area index values obtained

Table 1. Leaf area index values (cm^2) of the sunflower cultivars exposed to external glutamic acid treatments

Tabela 1. Indeks listne površine (cm^2) pri različnih sortah sončnic podvrženih tretiranju z glutaminsko kislino.

Leaf area index (cm^2)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	Glu-0	**Glu-100**	**Glu-200**	**Glu-300**	
Sakha	4.57i	4.76h	5.25f	5.64cd	**5.06c**
Aqmar	5.51de	6.26a	5.82c	5.70c	**5.82a**
Ishaki-1	4.93gh	4.98g	5.42ef	6.01b	**5.34b**
Mean Glu Con.	**5.00d**	**5.33c**	**5.50b**	**5.78a**	

SE± = 0.085
C. V. = 9.435

at different glutamic acid concentrations. Adeem (2015) also reported increasing leaf area index values with amino acid treatments. Consistent with the present findings, El-Hawary and Nashed (2019) reported significant effects of ascorbic and salicylic acid treatments on growth parameters of maize plants.

Chlorophyll Content (%)

In terms of chlorophyll contents of the varieties, the highest value (40.51%) was obtained from the variety Aqmar and the lowest value (39.03%) was obtained from the variety Sakha, with no significant difference between the variety Sakha and Ishaqi-1 (Table 2). There were significant differences in chlorophyll contents for the interactions. The highest value (41.50%) was obtained from Glu-100 (100 mg l^{-1}) treatments of the variety Aqmar and the lowest value (37.73%) was obtained from Glu-0 (control) treatments of the variety Sakha. Differences in chlorophyll contents of glutamic acid concentrations were not found to be significant. The highest value (40.38%) was obtained from Glu-100 (100 mg l^{-1}) treatments and the lowest value (38.53%) was obtained from Glu-0 (control) treatments.

Statistical analyses revealed that there were significant differences in chlorophyll contents of the sunflower varieties, since amino acid sprays reduced the harmful effects of stress factors and increased photosynthetic pigments (Sadak and Mostafa, 2015). Consistent with the present findings, Yan et al. (2011) indicated that proline treatments improved the defense mechanisms of horticultural crops against environmental stress, then promoted photosynthesis and enzyme activity. There were also significant differences in chlorophyll contents obtained at different glutamic acid concentrations, because amino acids worked as a growth regulator to maintain cell cytoplasm and build chlorophyll and carbohydrates (Al-Qaisi, 2016). Consistent with the present findings on chlorophyll contents, Hayat et al. (2012) found that amino acids acted on osmotic regulation of cells and protection of chromosomal systems under changing environmental conditions.

Table 2. Chlorophyll contents (%) of the sunflower cultivars exposed to external glutamic acid treatments.

Tabela 2. Vsebnost klorofila II (%) pri različnih sortah sončnic podvrženih tretiranju z glutaminsko kislino.

Chlorophyll Content (%)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	Glu-0	**Glu-100**	**Glu-200**	**Glu-300**	
Sakha	37.73f	39.57cde	38.83e	39.97bcd	**39.03b**
Aqmar	39.23de	41.50a	40.57abc	40.73ab	**40.51a**
Ishaki-1	38.63ef	40.07bcd	40.43abc	39.17de	**39.58b**
Mean Glu Con.	**38.53b**	**40.38a**	**39.94a**	**39.96a**	

SE± = 0.194
C. V. = 2.935

Percentage of Empty Seeds (%)

Table 3 shows that there were no significant differences in the percentage of empty seeds of the varieties. The highest value (75.29%) was obtained from the variety Ishaqi-1 and the lowest value (74.52%) was obtained from the variety Aqmar. Interactions had significant effects on percentage of empty seeds. The greatest value (80.26%) was obtained from Glu-200 (200 mg l^{-1}) treatments of the variety Sakha and the lowest value (66.10%) was obtained Glu-0 (Control) treatments of the same variety. Significant differences were also seen in percentage of empty seeds of different glutamic acid concentrations. The greatest value (77.86%) was obtained from the Glu-200 (200 mg l^{-1}) treatments and the lowest value (62.24%) was obtained from the Glu-0 (Control) treatments. There were no significant differences between Glu-200 and Glu-300 treatments.

In the present study, statistical analyses revealed that there were no significant differences in percentage of empty seeds of the sunflower varieties, but there were significant differences in percentage of empty seeds obtained at different glutamic acid concentrations. The reason may be due to the role of amino acid in reducing the negative impact of stress, especially the water stress to which the plant was exposed throughout different growth stages. Taylor et al. (2002) reported positive effects of amino acid treatments on vegetative growth parameters through increasing carbon metabolism, dry matter accumulation, thus increasing the pollinated seeds in the head. Mohamed and Khalil (1992) reported positive effects of arginine treatments on yields components of some winter plants. Present findings on percentage of empty seeds are also consistent with the findings of Alak (2016) indicating the role of proline in improving yield and yield components of sunflower under water stress conditions.

Oil Content (%)

Table 4 shows that there were significant differences in the oil contents of the sunflower varieties. The highest value (44.09%) was obtained from the variety Sakha and

Table 3. Percentage of empty seeds (%) of the sunflower cultivars exposed to external glutamic acid treatments.

Tabela 3. Delež praznih semen (%) pri različnih sortah sončnic podvrženih tretiranju z glutaminsko kislino.

Percentage of Empty Seeds (%)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	Glu-0	**Glu-100**	**Glu-200**	**Glu-300**	
Sakha	66.10h	75.56d	80.26a	78.05bc	**74.99a**
Aqmar	72.08f	73.99e	74.48de	77.51c	**74.52a**
Ishaki-1	69.52g	75.34d	78.85b	77.45c	**75.29a**
Mean Glu Con.	**69.24c**	**74.96b**	**77.86a**	**77.67a**	

SE± = 0.678
C. V. = 5.432

Table 4. Oil contents (%) of the sunflower cultivars exposed to external glutamic acid treatments.

Tabela 4. Vsebnost olja (%) pri različnih sortah sončnic podvrženih tretiranju z glutaminsko kislino.

Oil Content (%)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	Glu-0	**Glu-100**	**Glu-200**	**Glu-300**	
Sakha	41.96d	45.55b	44.60bc	44.26bc	**44.09a**
Aqmar	39.75e	42.25d	47.49a	45.62b	**43.78ab**
Ishaki-1	38.23e	43.64cd	48.05a	43.00cd	**43.23b**
Mean Glu Con.	**39.98c**	**43.81b**	**46.71a**	**44.29b**	

SE± = 0.494
C. V. = 6.788

the lowest value (43.23%) was obtained from the variety Ishaqi-1. The differences between the variety Aqmar and Ishaqi-1 were not found to be significant. Interactions had also significant effects on oil contents. The greatest value (48.05%) was obtained from Glu-200 (200 mg l^{-1}) treatments of the variety Ishaqi-1 and the lowest value (38.23%) was obtained from Glu-0 (Control) treatments of the same variety. There were significant differences in oil contents of different glutamic acid concentrations. The greatest value (46.71%) was obtained from the Glu-200 (200 mg l^{-1}) treatments and the lowest value (39.98%) was obtained from the Glu-0 (control) treatments. There were no significant differences between Glu-100 and Glu-300 treatments.

Statistical analysis revealed that there were no significant differences in oil contents of the sunflower varieties, but there were significant differences in oil contents obtained at different glutamic acid concentrations. As compared to the control treatment, glutamic acid treatments generally increased oil contents, due to the role of amino acids in protecting the plant from oxidation resulting from plant exposure to environmental stresses such as high temperature and lack of water, consequently preserve oils from oxidation (Al–Fhadoya, 2016). This result is consistent with what Majid and Al-Bahadli (2016) mentioned in their study of the effect of proline in reducing moisture stress and prolonging irrigation periods for sunflower crop, where it was found that increasing proline from zero to 100 mg l^{-1} led to an increase in oil content from 28.33% to 32%. Present findings on oil contents are also consistent with the results of Hamed (2016) indicating significant effects of salicylic acid treatments on oil content of safflower plants.

Protein Content (%)

For protein contents of the varieties, the highest value (15.51%) was obtained from the variety Ishaqi-1 and the lowest value (14.63%) was obtained from the variety Aqmar. There was no significant difference between the variety Sakha and Aqmar and between the variety Sakha and Ishaqi-1. Interactions had significant effects on protein contents (Table 5). The greatest value (18.22%) was obtained from Glu-100 (100 mg l^{-1}) treatments of the variety Ishaqi-1 and the lowest value (13.31%) was obtained from Glu-0 (control) treatments of the variety Aqmar. There were significant differences in oil contents of different glutamic acid concentrations. The greatest value (16.51%) was obtained from the Glu-100 (100 mg l^{-1}) treatments and the lowest value (13.57%) was obtained from the Glu-0 (control) treatments. There was no significant difference between Glu-0 and Glu-200 treatments and between Glu-100 and Glu-300 treatments.

Statistical analyses revealed that there were significant differences in protein contents of the sunflower varieties, probably because of the differences in genetic structures of the varieties (Alsubaihi et al., 2020). There were also significant differences in protein contents obtained at different glutamic acid concentrations. Glutamic acid treatments increased protein contents since foliar application with amino acids can stimulate growth by increasing the activity of the antioxidant enzymes, thus it prevents protein loss and enhances the photosynthetic pigment (Paul and Nair, 2015). Al-Seedi and Al-Badry (2015) indicated that increasing acid concentrations encouraged the absorption of the basic elements for protein production (sulfur, phosphorous,

Table 5. Protein content (%) of the sunflower cultivars exposed to external glutamic acid treatments.

Tabela 5. Vsebnost proteinov (%) pri različnih sortah sončnic podvrženih tretiranju z glutaminsko kislino.

Protein Content (%)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	Glu-0	**Glu-100**	**Glu-200**	**Glu-300**	
Sakha	13.63d	15.73bc	14.23cd	17.28ab	**15.22ab**
Aqmar	13.31d	15.59c	13.95d	15.68bc	**14.63b**
Ishaki-1	13.77d	18.22a	14.39cd	15.68bc	**15.51a**
Mean Glu Con.	**13.57b**	**16.51a**	**14.19b**	**16.21a**	

SE± = 0.276
C. V. = 10.933

and nitrogen) and the activity of some enzymes to make a protein. Raskin (1992) and Webber and Bledsoe (2002) also indicated that acid treatments promoted the production of proteins and some other compounds effective in inhibition of the activity of proteolytic enzymes such as proteases and peptidases.

Conclusions

The present study indicated that there were significant differences in leaf area index, chlorophyll content, empty seed rate, oil content, and protein content of the sunflower varieties.

According to the results of the study, the highest leaf area index was measured as 5.82 cm^2. The 100 mg l^{-1} glutamic acid treatments of the variety Aqmar yielded the highest chlorophyll content (40.51%). The 100 mg l^{-1} glutamic acid treatments of the variety Ishaqi-1 had the highest protein content (15.51%).

There were no significant differences in oil contents of the sunflower varieties, but there were significant differences in oil contents obtained at different glutamic acid concentrations. As compared to the control treatment, glutamic acid treatments generally increased oil contents. Statistical analyses revealed that there were significant differences in protein contents of the sunflower varieties, and, in general, glutamic acid treatments increased protein contents.

As a conclusion, the external glutamic acid application could have positive effects on the quality of sunflower.

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