T.R.
ERCIYES UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF AGRICULTURAL SCIENCES AND TECHNOLOGIES

THE EFFECT OF GLUTAMIC ACID SPRAYING ON GROWTH AND YIELD OF SUNFLOWER (*Helianthus annuus* L.) VARIETIES

Prepared
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Master's Thesis

January, 2022
KAYSERİ

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COMPLIANCE WITH SCIENTIFIC ETHICS

I declare that all the information in this study was obtained in accordance with academic and ethical rules. I also state that I have fully cited and referenced all materials and results that are not inherent in this study, as these rules and behavior require.

RIYADH TAHA DWAYYEH DWAYYEH

Signature ……

SUITABILITY FOR GUIDE

The MSc thesis entitled "**The Effect of Glutamic Acid Spraying On Growth and Yield of Sunflower (*Helianthus annuus* L.) Varieties"** has been prepared in accordance with Erciyes University Graduate School of Natural and Applied Sciences Institute Thesis Preparation and Writing Guide.

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Riyadh Taha DWAYYEH

Kayseri, January 2022

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Erciyes University, Graduate School of Natural and Applied Sciences
M.Sc. Thesis, January 2022
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ABSTRACT

The present thesis was conducted to determine the effects of glutamic acid treatments at different doses on yield and growth parameters 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 split-plots experimental design with three replications under Anbar-Iraq conditions in 2021. 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, leaf area index as 5.82 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 chlorophyll content (40.51%) and 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 $plant^{-1}$) and protein content (15.51%). 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}). The 200 mg l^{-1} glutamic acid treatments of the variety Ishaqi 1 were superior in percentage of empty seeds (75.29%) and oil content (44.09%). In general, the highest vegetative growth (stem height) (194.25 cm) and the highest seed yield (4.87 t ha^{-1}) were obtained from 300 mg l^{-1} glutamic acid treatments of the variety Aqmar.

Key Words: Sunflower, Amino Acids, Glutamic Acid, Vegetative Growth, Yield.

GLUTAMİK ASİT UYGULAMASININ AYÇİÇEĞİ (*Helianthus annuus* L.) ÇEŞİTLERİNDE VERİM VE KALİTEYE ETKİSİ

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ÖZET

Bu çalışma, farklı dozlarda glutamik asit uygulamalarının bazı ayçiçeği çeşitlerinde büyüme karakterleri ve verim üzerine etkilerini belirlemek amacıyla yapılmıştır. Glutamik asit, üç ayçiçeği çeşidine (Sakha, Aqmar ve Ishaqi 1) dört farklı konsantrasyonda (0, 100, 200 ve 300 mg l^{-1}) yapraktan püskürtme şeklinde uygulanmıştır. Tarla denemeleri 2021 yılında Anbar-Irak koşullarında tesadüf blokları bölünmüş parseller deneme desenine göre üç tekrarlamalı olarak kurulmuş, glutamik asit konsantrasyonları alt parsellere, çeşitler ise ana parsellere gelecek şekilde yerleştirilmiştir.

Çalışma sonuçlarına göre, verilerin ortalaması olarak en yüksek bitki boyu 194.25 cm, yaprak alanı 10188.70 cm^2, yaprak alan indeksi 5.82 cm^2, bitki başına yaprak sayısı 23.93 adet, bitki kuru ağırlığı 181.22 g/bitki, bitki başına tohum verimi 49.17 g ve tohum verimi 4.87 ton/ha olarak belirlenmiştir. Biyolojik verim 17.98 ton/ha olmuş, en yüksek gövde çapı 25.77 mm olarak Ishaqi 1 çeşitdinden elde edilmiştir.

Tabla çapı ve klorofil oranı bakımından en yüksek değerler (sırasıyla 17.52 cm ve %40.51) Aqmar çeşidinde, 100 mg l-1 glutamik asit konsantrasyonu ulgulamasından elde edilmiştir. Aynı dozda (100 mg l^{-1}) glutamik asit uygulamasında, tablada tane sayısı (850 adet/bitki) ve protein oranı (%15.51) bakımından Ishaqi 1 çeşdi daha iyi sonuç vermiş ve Sakha çeşidinde en yüksek yağ oranına (% 44.09) ulaşılmıştır.

Bu çalışmanın genel bir sonucu olarak, en yüksek vejatatif büyümenin (194.25 cm) ve en yüksek verimin (4.87 t ha) 300 mg l^{-1} glutamik asit uygulamasında Aqmar ayçiçeği çeşidinden elde edildiği gözlenmiştir.

Anahtar Kelimeler: Ayçiçeği, Amino Asit, Glutamik Asit, Vejetatif Büyüme, Verim.

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ICONS AND ABBREVIATIONS

% **:** Percentage

C.V. **:** Coefficient of Variation

ds/m **:** Deci Siemens per meter

EC **:** Electrical Conductivity

g **:** Gram

GA0 **:** Zero Glutamic Acid Concentration (Control)

GA100 **:** Glutamic Acid Concentration (100 ml/L^{-1})

GA200 **:** Glutamic Acid Concentration (200 ml/L^{-1})

GA300 **:** Glutamic Acid Concentration (300 ml/L^{-1})

ha **:** Hectare

mm **:** Millimeter

mM **:** Milimol

SE± **:** Standard Error

V1 **:** Sakha Variety

V2 **:** Aqmar Variety

V3 **:** Ishaqi 1 Variety

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CHAPTER ONE

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 (Al-Fahaadi, 2012). Sunflower is an important oil crop because it gives the largest amount of oil per unit of the cultivated area due to the high oil content of its seeds, which may reach up to 50%. Sunflower oil is characterized by a good taste, so it is widely used in the manufacture of high-quality edible oils, butter, bread products and biscuits, as well as in the manufacture of soap and dyes. As for the stems, they can be used as fuel (Oğuz, 2019).

Recently, importance of the oil crop has increased as a result of the shortage in the produced quantity of oils in the world, as it ranks the second second in terms of production after the soybean and the first in oil production of Iraq (Al-Rawi & Kavanagh, 1998). The importance of the sunflower crop comes from the fact that its seeds contain a high percentage of oil that reaches nearly 50% of the seeds of some of its improved varieties, in addition to high taste characteristics of the oil (Khalaf & Rahman, 2015). The productivity of this crop in Iraq is still below the desired levels due to the failure to follow the correct scientific methods in soil preparation and the other agronomic practices.

Improving the local production of sunflower depends on the production of new genetic structures that are characterized by their high ability to produce high productions of this crop and this depends on introduction of high-yield hybrids into the markets. The introduction of the distinguished hybrids into the country will be possible only through

studying the extent of their adaptation to climatic conditions and determining the appropriate ones (Rao et al., 2004). Then the breeders have more than one option to produce good combinations of them, produce pure strains of these hybrids, produce synthetic varieties or use mutations on these hybrids and other breeding methods.

Most farmers evaluate sunflower hybrids on the basis of seed yield, which is greatly affected by environmental conditions, as is any quantitative characteristics, so it changes from year to year according to climatic conditions (Kaya et al. 2007). As for plant breeders, they evaluate the hybrids on the basis of the yield components that indirectly increase the seed yield when selecting for them.

The difference in yield and yield components of the genotypes mostly comes from the difference in the physiological processes of these genotypes after flowering (de la Vega & Hall, 2002). Several studies have been conducted to compare different genotypes of sunflower, most of which indicated that the characteristics of leaf area, head diameter and seed weight were positively correlated with seed yield (Kaya et al. 2007).

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 acid concentrations and abscisic acid levels significantly influence the process of opening and closing of stomata. When the plants are exposed to stress conditions, such as high heat, the rate of demolition in the plant is higher than the rate of construction and such a case in turn slows down the plant metabolism.

When amino acids, especially glutamic acid, are sprayed, they act as an osmotic equilibrium coefficient in the cytoplasm of the guard cells and this also improves the process of opening and closing of plant stomata. Amino acids also increase plant immunity and vitality to resist severe weather changes and chelate nutrients, which helps prevent these elements from accumulating in their complex form in the soil or plants, and this raises the level of nutritional benefit from these elements as they are easily transported within the plant. Valine and methionine have an important role in increasing the rate of radicals and their spread and thus the continuation of the movement of water between the soil and the plant, so the plant remains in its healthy state (Meister, 2012).

Glutamic acid and the other flavors of amino acids were scientifically identified as early as the 19th century, in 1866 by the German chemist Carl Heinrich Reithausen. Amino acids are the main component of protein. Amino acids act as powerful chelating agents for microelements, as the molecular weight of amino acids is very small, which facilitates the penetration of the microelements associated with them into the plant. They also increase the plant tolerance to adverse and difficult conditions such as heat, drought, salinity and frost. 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 and poor health (Farid et al., 2020).

The present thesis was conducted to;

- Determine the effects of foliar glutamic acid treatments at different concentrations on various morphological, agronomic and quality traits of different sunflower varieties,
- Assess the performance of some oil-type sunflower varieties under environmental conditions of Iraq, which are characterized by high temperatures throughout the growing season.

CHAPTER TWO

GENERAL INFORMATION AND SUMMARY OF LITERATURE

2.1. Sunflower Crop

Sunflower (*Helianthus annuus* L.) belongs to Asteraceae (Compositae) family. It is one of the most important oil crops grown in the world. Sunflower plants are characterized by flowering discs that move with the movement of the sun until seed formation stage. Its growth period ranges between 90 - 120 days. It is largely cultivated in Russia, Ukraine, Argentina, Europe, China, the USA and India (FAO, 2012). Sunflower is mostly grown for seeds with about 30-50% oil content. Sunflower oil is rich in unsaturated fatty acids (such as oleic, linoleic and linolenic acid) and unsaturated fatty acids constitute about 90% of the total fatty acids in the plant. Unsaturated fatty acids reduce blood cholesterol levels and thus reduce the chance of heart attacks, as well as sclerosis diseases. Sunflower is considered as one of the best oils suitable for food because it contains a group of vitamins such as A, D and E, which play an important role in prevention of oxidation, making it one of the best vegetable oils to be consumed at the global level.

Sunflower is the first oil crop in Iraq (Ali Atiyah & Hasson Kadhim, 2019). 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. Sunflower growth and development is largely designated by environmental factors and plant genetics and their interactions. Relevant agronomic practices should efficiently be performed to increase yields and to improve quality. Previous and current studies have proven that foliar sprays were an effective means of supplying nutrients to increase yield and quality.

2.1.1. Genetic Structures and Varieties

There are several sunflower genotypes available for cultivation in different regions of the world and several studies have been conducted on yield, yield components and quality traits of sunflower varieties. Such a case proves the economic importance of the crop. Researchers should use the correct scientific methods when dealing with varieties or hybrids. Since sunflower is an oil crop, treatments should so be selected as to get the highest percentage of oil and protein ratios from the studied genetic materials.

Hameed et al. (2019) applied nitrogen fertilizers at different concentrations to three sunflower genotypes (Flame, Urflo, and Manon) and reported significant increases in oil ratios of Manon and Euroflor genotypes with increasing nitrogen concentrations. This confirms that oil content of sunflower seeds was a quantitative trait controlled by a large number of genes. It was also indicated that genetic structure and oil ratios were influenced by environmental factors and agronomic practices, especially by successive fertilizer doses.

In another study, Al-Waeli et al. (2018) found that certain proportions of potassium and boron significantly affected yield and growth parameters of Lilo sunflower cultivar. Fertilization treatments improved phenotypic characteristics of the variety and increased qualitative characteristics of seeds and oil. Total oil yield reached to 1.93 tons/ha^{-1}. Such a case proved that interactive effects of potassium and boron yielded high ratios and averages of the studied traits and improved oil quality of Lilo sunflower cultivar.

Nasralla et al. (2014) conducted a study on two different sunflower cultivars (Aqmar and Shmoos) and investigated the effects of foliar plant extract sprays on yield and quality traits of sunflower cultivars. It was found that plant extracts had a clear effect on the studied traits and their positive effects directly reflected on seed yield and protein ratios. It was recommended that plant extracts and antioxidants could reliably be used as safe natural alternatives to obtain the best production per unit area.

2.1.2. Economic Importance of the Crop

Sunflower is one of the most important oil crops in the world. It gives the largest amount of oil per unit of the cultivated area because its seeds contain a high percentage of oil up to 50%. The seed oil of this crop is characterized by its good taste, so 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. Its seed meal is good source of fodder for farm animals because it contains 36% proteins, 20-22% carbohydrates and up to 6% fat. As for the stems, they can be used as fuel and the remaining ash can be used in potassium oxide extraction. Extracted potassium oxide is used in potassium carbonate production. Potassium carbonate is largely used in chemical industry, especially in manufacture of chemical fertilizers, as well as in glass and adhesive industries (Li et al., 2018). Sunflower fields are also used in beekeeping to absorb the nectar of flowers to produce honey, which in turn leads to an increase in the rate of pollination. It is also considered as an ornamental plant, especially in large gardens, where it is grown to decorate basins and flats, and on the banks of streams and ponds, because of its beautiful shape that pleases the beholder. It is also grown in windy areas and is used as a windbreak in cotton and vegetable fields. Iraq is ranked fifth after Morocco, Syria, Egypt, and Tunisia in terms of the area planted with the crop.

2.2. Amino Acids

Amino acids are the basic units responsible for the formation of protein molecule. They are organic carbonic acids consisting of amines (NH2) and carboxylic acids (COOH) in addition to the alkyl (R) of each amino acid whose side chain is attached to the carbon (α) atom. They are also organic acids that are often ionized at a pH of approximately 7 (Baqir et al. 2019). A general representation of amino acids is presented in Figure 1.

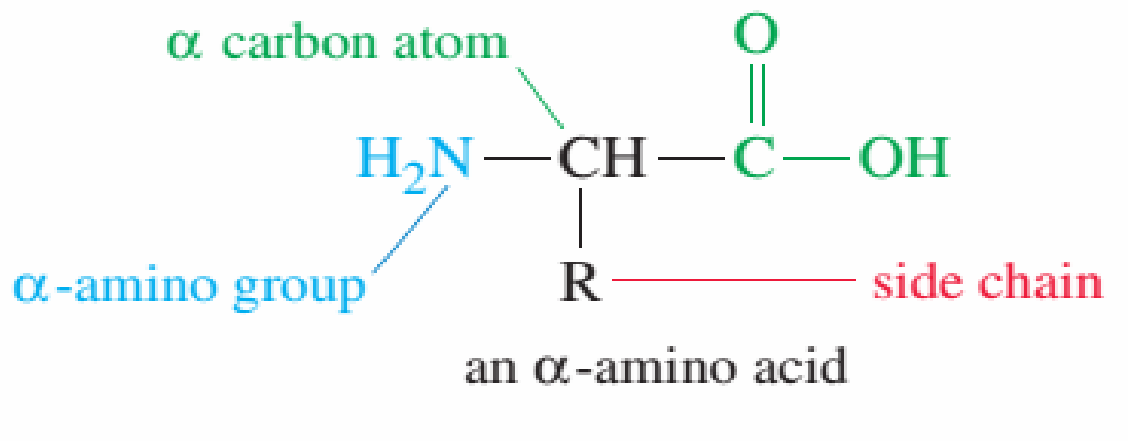


Figure 1. General chemical formula of amino acids.

2.2.1. Types of Amino Acids

2.2.1.1. Essential amino acids

They are the ones that a person cannot synthesize inside his body and must be added to the food until the body gets enough of them. They are composed of eight acids (valine, leucine, isoleucine, tyrosine, lysine, methionine, tryptophan, and phenylalanine) (Yaseen, 2001).

2.2.1.2. Semi-essential amino acids

The body can synthesize them, but in insufficient quantities. They include histidine and arginine.

2.2.1.3. Non-essential amino acids

They are ordinary amino acids that the body can make or take from food and they represent the rest of the amino acids.

2.2.1.4. Anti-amino acids

They are ordinary amino acids, but they change their structure, thus disrupting their chemical reactions. They include ethionine and an ethyl group replaces a methyl group in methionine (Yaseen, 2001).

There are 21 types of amino acids divided into two parts: peptides and protein (Abood, 2009). Amino acids are bio-catalysts that nourish plants with energy to compensate for the losses caused by the processes of respiration and decomposition. They are also characterized as colorless ionic compounds that are soluble in cold and hot water. Because they are hybrid ions, the percentage of alcohol in them is in varying degrees and high melting degrees. Plant amino acids are either free or shared with each other (proteins and peptides), knowing that the free form is common where it breaks down into small bonds, making them free, single and easy to use (Abou Gamra et al., 2011). Amino acids also widely present in mitochondria and chloroplasts of living organisms.

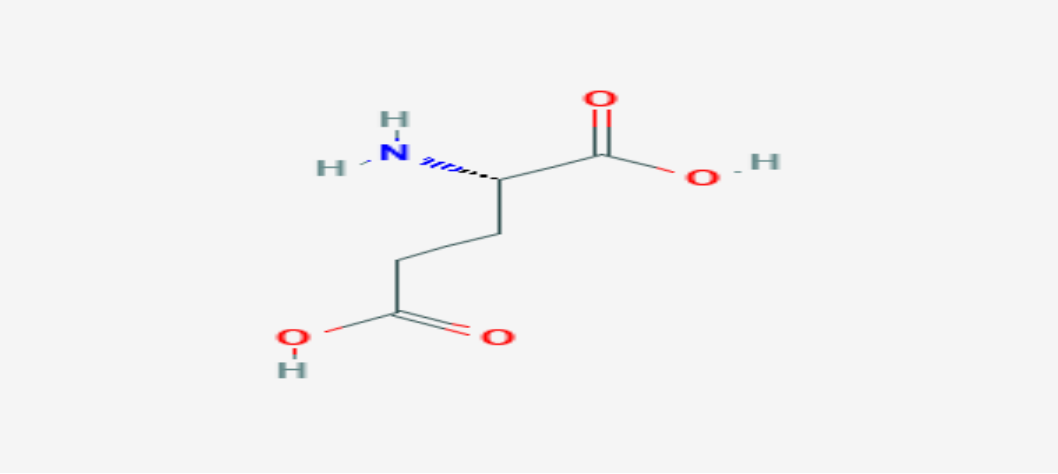
2.2.2. Importance of Amino Acids for Plants

Amino acids and their activities in different plant growth stages increase the ability of the cell to absorb water and solvent 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 (Dromantiene, Pranckietiene, Šidlauskas, & Pranckietis, 2013; Sharma-Natu & Ghildiyal, 2005). They are formed to synthesize other substances such as vitamins, nucleotides and growth regulators. They are essential components of living organisms and protoplasm, contribute to the synthesis of intracellular enzymes and are believed to be responsible for enhanced protein contents, cell division, plant pigments and natural hormones such as IAA, GA3 and ethylene. Amino acids also enhance the grain quality of some crops and increase mineral absorption. They play an important role as a chelating agent for iron, zinc, copper, magnesium and calcium, as it can be easily absorbed and passed through the plant with the aid of amino acids (Vernieri et al., 2005). Amino acids are an important source of nitrogen and therefore have a significant impact on crop growth (Barner, 2016).

2.3. Glutamic Acid

It is one of the amino acids that make up the proteins of all organisms and one of the most abundant ones in the nature. Since organisms have intrinsic pathways for their biosynthesis, it is not considered essential (Forde & 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 as "glutamic" acid. After the discovery, its presence was determined in a large part of living organisms, that is why, it is believed to have essential functions for life.

It 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. Schematic representation of a glutamic acid molecule is presented in Figure 2 and physico-chemical properties are provided in Table 1.



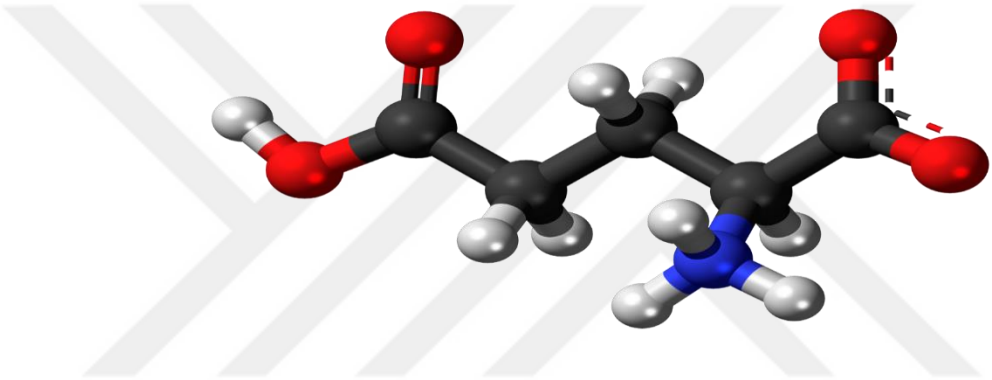


Figure 2. Schematic representation of glutamic acid molecule

Table 1. Physical and chemical properties of glutamic acid

Chemical formula	**C5H9NO4**
Molar mass	147.13 g/mol^{-1}
Appearance	White crystalline powder
Density	1.4601 in 25 C^0
Melting point	199
Boiling Point	205 C^0
Water solubility	8.64 g/l in 25 C^0
Pka. dissociation constant	4.25
Protein index	7%

Physiological importance of glutamic acid in plants:

Glutamic acid plays important roles in plant metabolism. In terms of physiological aspects, glutamic acid has multiple functions as follows:

- It enters into the composition of chlorophyll, which leads to an increase in the rate of photosynthesis.
- It enters into cytoplasm of the guard cells as an osmotic regulator, thus improving the process of opening and closing of plant stomata when the plants are exposed to high-heat so that the rate of demolition is higher than the rate of construction.
- It has a central role in the balance between carbon and nitrogen within the plant, as well as the synthesis of important proteins.
- Represents a central place in the metabolism of amino acids because most of the amino acids can be derived from them.
- It is the main source for storing and transporting organic nitrogen in the plant cell.
- It works to increase the vegetative growth and earliness in the crop and its presence is considered effective in the process of pollination in fruits and early flowering (Oseyko et al., 2020).

2.3.1. Effect of Glutamic Acid on Growth and Yield of Sunflower Plants

Glutamic acid releases special signals as a growth material. It plays an important role in balancing nutrients through plant tissues and increases the consumption and absorption of elements in addition to building carbohydrates and proteins in the plant and improving physiological characteristics (Forde & Lea, 2007).

Al-Bahadli et al. (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 x irrigation duration interactions had significant effects on most of the studied traits. The highest

average stem height (126.19 cm), average leaf area (0.41 m^2) and average seed weights (352.30 - 361.45 kg/m^3) were obtained from 100 mg l^{-1} proline concentration. Seed oil contents also increased with increasing amino acid concentrations.

Alak et al. (2016) conducted field experiments on 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%), 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-Qaisi et al. (2016) conducted field experiments to study the effects of adding glutamic acids at two concentrations (50 and 100) mg l^{-1} on yield and growth parameters of wheat plant (*Triticum eastivum* L.). With glutamic acid treatments, significant increases were seen in most of the physiological characteristics, such as 76.66% and 66.66% increases in stem diameters, 16.66% and 66.66% in number of leaves, 23.30% and 7.69% in plant heights, 97.43% and 61.40% in leaf areas and 65.85% and 37.28% in dry weights as compared to the control treatments.

Al-Bahadly et al. (2021) conducted field experiments during the fall season of 2014 to study yield, growth parameters and crop response of Flame sunflower variety to different irrigation intervals (10 and 15 days) and different foliar proline concentrations (50 and 100 mg l^{-1}). It was seen that irrigation intervals and proline concentrations had significant effects on majority of investigated traits. 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.

Hassan et al. (2014) conducted field experiments for two seasons to study the effects of different irrigation treatments (30%, 50% and 70%) and ABA concentrations (0, 2.5, 5 and 7.5 µmol) on some phenotypic growth characteristics and root dry weight of sunflower plants. As the average of two seasons, 70% irrigation treatments yielded an average plant height of 128 cm, leaf area of 0.45 m^2 $plant^{-1}$, crop growth rate of 12.80 gm/m^2day^{-1}, root dry weight of 30.85 gm $plant^{-1}$. Again, as the average of two seasons,

the greatest average root weight (28.81 g plant^{-1}) and crop growth rate (9.95 g/m^2. day^{-1}) values were obtained from 7.5 µmol ABA concentration.

Dahi et al.(2015) conducted field experiments on the experimental fields of the Department of Soil Sciences and Water Resources - College of Agriculture - University of 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 superior and this treatment yielded an average leaf area of 0.3494 m^2, total chlorophyll content of 0.802% and seed yield of 7.90 t ha^{-1}. The 50% water stress treatments yielded an average leaf area of 0.3925 m^2 and seed yield of 7.70 t ha^{-1}. Proline concentrations did not have significant effects on most of the investigated traits. Combined sprays of proline and salicylic acid (150 mg l^{-1} + 200 mg l^{-1}) were also superior and these treatments yielded an average leaf area of 0.3904 m^2 and seed yield of 8.30 t ha^{-1}. Proline treatment with 50% moisture level (150 mg l^{-1} + 50%) yielded an average leaf area of 0.4121 m^2, dry weight of 418.7 g and seed yield of 8.13 t ha^{-1}. Salicylic acid treatment with 50% moisture level (200 mg l^{-1} + 50%) yielded the highest values for leaf area (0.4069 m^2) and seed yield (8.27 t ha^{-1}). Combined proline + salicylic acid + water stress treatments (150 mg l^{-1} + 200 mg l^{-1} + 50%) yielded an average leaf area of 0.4634 m^2, dry weight of 453.3g plant^{-1} and seed yield of 9.09 t ha^{-1}.

Abood et al. (2018) conducted field experiments in the Agricultural Experimental Farm of the Agricultural Engineering Department - College of Agriculture - the University of Anbar for two seasons to investigate the effects of amino acids (tryptophan, arginine and tyrosine) at different concentrations (0, 100, 200 mg l^{-1}) on yield and growth parameters of three wheat varieties (Al-Rashed, Al-Tamuz 2, Abu Ghraib 3). The results showed a significant difference in the studied traits, as the application of tryptophan led to an increase in the length of the spike in the first season and the 1000-grain weight in the second season. While tyrosine spraying yielded the highest average number of spikes per m^2 in the first season, number of grains per spike varied between 47.33 - 49.94 for both seasons, grain yields varied between 5.92 and 6.83 t ha^{-1}, while it showed no significant effect on the harvest index. Amino acid concentrations had

significant effects on spike length, number of grains per spike, 1000-grain weight and grain yields. The concentration of 200 mg l^{-1} gave the highest grain yield values of 6.27 and 7.16 t ha^{-1} for both seasons, respectively, while it had no significant effect on grain yield and harvest index. Al-Rashid cultivar was superior in spike length and number of grains per spike (47.86 and 49.19 grains), 1000-grain weight (34.12 and 35.49 g $plant^{-1}$), grain yield (6.32 and 7.09 t ha^{-1}) and harvest index for both seasons, respectively.

2.3.2. Effect of Cultivars on Vegetative Growth Characteristics:

The characteristics of vegetative growth are considered as one of the most important aspects of the biological and physiological activity of the plant, as it indicates the extent of interaction between the environmental factors and the variety.

Aldemir et al. (2016) conducted a study on fourteen hybrids of sunflower in Turkey and indicated that hybrid ETAE-TM-4 yielded the highest average plant height (201.5 cm). It was followed by TANAY hybrid (194.4 cm) and hybrid P64G6(St-2) yielded the lowest average plant height (155.5 cm).

AL-Jebouri et al. (2017) conducted field experiments on in two genetic structures of sunflower (Ishaqi 1 and Banam) in two sites and indicated that Ishaqi cultivar was significantly superior, as it recorded the highest average plant heights (128.54 and 129.18 cm) in both sites, respectively, while the cultivar Panam recorded the lowest average plant heights (116.71 and 108.62 cm) in both sites, respectively.

Sarheed et al. (2015) conducted field experiments on three sunflower cultivars (Flamy, Urflo, F.S) in the city of Ramadi and indicated that the cultivar Urflo was significantly superior with the highest average plant height of 162.60 cm and stem diameter of 139 mm, while the F.S variety yielded the lowest average plants height of 147.86 cm and the stem diameter of 125 mm.

Carrillo-Ávila et al. (2015) 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 stem diameters of the sunflower hybrids and the hybrid Fullsum had the highest average plant height of 192.8 cm and stem dimater of 250 mm.

Alak et al. (2010) conducted a research with several sunflower genotypes for two seasons on experimental fields of College of Agriculture, University of Baghdad and indicated that Ibis genotype had significantly higher leaf area values (7076 cm^2 and 8161 cm^2) in two seasons and two genotypes (Aqmar and Florasol) had the lowest values of both traits in two seasons.

Nehme et al (2009) conducted a study with two sunflower genotypes (Aqmar and Flamy) in Al-Shihabi district of Anbar Governorate and indicated that two genotypes differed significantly in leaf area characteristic of the spring and autumn ligules. The genotype of Amar had the highest value in the spring season (8183.25 cm^2) as compared to the cultivar Flamy with a value of 6780.71 cm^2.

Hamza et al. (2011) conducted a study on two different sunflower cultivars (Record and Hybrid) and reported that the hybrid cultivar had significantly higher number of leaves per plant (15.44 leaf $plant^{-1}$)the Record cultivar yielding the lowest average for the trait.

Al–Fhadoya et al. (2016) 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-Salem et al. (2013) conducted field experiments on two sunflower cultivars (Urflo, Flam) in Dhi Qar city - Iraq to study some traits, including leaf area and indicated that Flam variety had the highest average leaf area (2.087 cm^2) and Euroflor variety had the lowest mean value for leaf area.

Sarwar et al. (2013) conducted a study in Pakistan on several hybrids of sunflower and reported significant differences in leaf area values of the hybrids. The hybrid SF-187 achieved the highest mean of the trait (4.33 cm^2), it was followed by the hybrid Hysun-33 (4.14 cm^2) and G-101 hybrid yielded the lowest average for the trait (2.83 cm^2).

Hamza et al. (2011) found in an experiment on two cultivars of sunflower (Record and Hybrid) in the city of Musayyib, which belongs to Babylon Governorate, that the hybrid cultivar was significantly superior in dry weight (54.33 g $plant^{-1}$), while the Record cultivar gave the lowest average for the trait.

Singh et al. (2005) indicated in a study of some traits of six sunflower hybrids that there were significant differences in dry weight of the hybrids. The cultivar Lsfh-171 yielded the highest average dry weight (78.4 g plant^{-1}), while the cultivar Kbsh-53 recorded the lowest average for the trait (58.2 g plant^{-1}).

A field experiment was conducted with two sunflower cultivars (Iraqi flower, Aqmar) in Babylon Governorate in spring and autumn seasons of 2015 and results showed that there were no significant difference in chlorophyll content of two cultivars in the spring season, while in the autumn season, the Iraqi flower cultivar was significantly superior in chlorophyll content (43.99 spad).

2.3.3. Effect of Varieties on Yield and Yield Components

Yield components of sunflower plants include head diameter, number of seeds per head, 1000-seed weight. Besides physiological and morphological processes, environmental conditions also have also significant effects on yield and yield components of sunflower plants. On the other hand, genotype itself or plant genetics play a great role in yield components.

Hamza et al. (2011) conducted field experiments on two sunflower cultivars (Record and Hybrid) and reported that Hybrid cultivar had the highest average head diameter (10.22 cm) and number of seeds per head (525.079 seed head^{-1}).

Ramadan et al. (2021) 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}).

Dutta et al. (2011) worked on three different sunflower cultivars (Kbsh1, Kbsh44 and Bac1091) and reported that cultivar Kbsh44 had the greatest average seed yield as 1361 kg ha^{-1}.

Kaleem et al. (2011) found in a study of four cultivars of sunflower (Alisson-rm, Parasio24, Mg-42 and S-278) that the cultivar Mg-42 was significantly superior in total seed yield (1984 kg.ha^{-1}).

Abdel-Hafeez et al. (2019) conducted field experiments on sunflower variety Sakha 54 for two seasons in Egypt to study the effects of foliar ascorbic acid sprays on yield components. It was reported that seed yield per plant of 26.3 g plant^{-1} in the control treatment increased to 32.4 g plant^{-1} in the first season and seed yield per plant of 25.7 g plant^{-1} increased to 32.0 g plant^{-1} in the second season with ascorbic acid treatments.

Shaker et al. (2010) conducted field experiments on three different sunflower genotypes (Kuban, Pyrodrovic and Zahrat al-Iraq) in two different locations. There were significant differences in 1000-seed weights of the genotypes. While the genotype Pyrodrovic had the highest mean values of the relevant trait (75.9 g plant^{-1} and 74.5 g plant^{-1}), Zahrat al-Iraq recorded the lowest averages (67.0 g plant^{-1} and 64.5 g plant^{-1}).

Sarwar et al. (2013) found in a study conducted in Pakistan on several hybrids of sunflower that significant differences were seen in 1000-seed weights of the hybrids. The hybrid SF-187 had the highest mean of the trait (49.11 g plant^{-1}), it was followed by the hybrid Hysun-33 (48.96 g plant^{-1}), which did not differ significantly from the hybrid Nx-00997 with the lowest average for the trait (48.12 g plant^{-1}).

Mahdi et al. (2009) indicated in a study of two sunflower cultivars (Pyrodrovic and Aqmar) that there was a significant increase in harvest index of Pyrodrovic cultivar (38.30%) as compared to the other cultivar Aqmar (33.47%).

Nehme et al. (2009) carried out field experiments on two different sunflower cultivars (Flame and Aqmar) in spring and autumn seasons. While the Flame cultivar had the highest averages for harvest index (32.97% and 28.27%) for two seasons, respectively, the Aqmar cultivar recorded the lowest means for the trait (27.53% and 24.87%) for two seasons, respectively.

In a field experiment carried out at the Abu Ghraib Research Station to study some traits of three genotypes, the results showed significant differences in the fertility rates of the genotypes. While the genotype Urflu had the highest value for the trait (95.38%), the Pan7392 genotype recorded the lowest average for the fertility rate (93.7%).

In a study carried out in Pakistan on two hybrids of sunflower cultivars (Hysun-33, Dk-4040), Hysun-33 recorded a significant increase and gave the highest average for biological yield (14.502 t ha^{-1}).

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%).

Al-Fahadi et al. (2012) mentioned in a study conducted in Mosul on three genotypes of sunflower that there was a significant difference in oil contents of the genotypes and the local genotype recorded the lowest average for oil content (22.4%).

Youssef et al.(2017) conducted field experiments to investigate the effects of different salicylic acid concentrations (0, 0.7 and 1.4 Mm) and salinity levels on yield and growth parameters of sunflower cultivars. It was reported that 1.4 Mm concentration at 4 Ds m^{-1} salinity level yielded the highest protein ratio (14.2%) and the control treatment had the lowest protein ratio (12.6%).

Abdel-Hafeez et al. (2019) conducted field experiments on sunflower variety Sakha 54 for two seasons in Egypt to study the effects of foliar ascorbic acid sprays on yield components. It was reported that protein ratio of 54.3% in the control treatment increased to 62.3% in the first season and protein ratio of 60.4% increased to 66.9% in the second season with ascorbic acid treatments.

CHAPTER THREE

MATERIAL AND METHOD

Field experiments were carried out in a private field in the city of Hit, in Anbar Governorate, western Iraq during the spring season of 2021. Experimental fields are located between 33°37'54.0" N latitude and 42°50'55.8" E longitude with an average altitude of 70 meters.

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. Experiments were conducted in randomized blocks split-plots experimental design with three replications. There were 36 experimental plots. Glutamic acid concentrations were placed into the sub-plots and sunflower cultivars were placed into the main plots.

Experimental lands were prepared by two orthogonal plows with flip-up plow, then smoothing and leveling was practiced with a fine-toothed plow (Figure 2). Soil samples were taken from the experimental fields and analyzed for physical and chemical properties (Table 2). The land was divided into three replicates randomly with 12 plots for each replicate (Figure 4). Experimental plots were 3.50 m long and 2.80 m wide (9.8 m^2). There was 1 m distance between the plots and 2 m between the blocks (Figure5). For weed control, Terfilan pesticide (48% trifluralin) was sprayed to experimental fields (Figure 6) (Pandya, 2018). Diammonium Phosphate (DAP) (NP 46%) and P_2O_5 (N 18%) fertilizers (200 kg/ha) were also applied to experimental fields at sowing (Figure 7) (Schlegel & Grant et al. 2015).

Sowing was performed on 3/08/2021 at 0.70 m row spacing and 0.25 m on-row plant spacing (Figure 8). Three seeds were placed in each seedbed to a depth of 3-5 cm. Irrigation was practiced after the completion of sowing (Figure 9) and the second batch

of nitrogen fertilizer was added (150 g urea, 48% N) for each experimental unit on the surface of the soil (Figure 10 and 11).

Glutamic acid solutions were prepared at differentconcentrations (0, 100, 200 and 300 mg l^{-1}). Two foliar sprays were performed: the first one at the beginning of plant growth stages to increase vegetative growth and the second one at the beginning of head formation to facilitate the process of formation (Figure 12) and the other agronomic practices were performed on time(Figure 13)

Table 2. Soil physical and chemical properties.

CaO, %	25.3885	P_3O_5, %	0.6794
SiO_2, %	34.3697	pH	7.9
Al_2O_3, %	9.9972	EC, $ds.m^{-1}$	1.15
Fe_2O_3, %	4.3556	Sand, %	42.50
MgO, %	7.6495	Silt, %	52.00
SO_3, %	0.3572	Clay, %	5.50
NaO, %	2.5757	Organic matter, %	25
K_2O, %	0.3833	Texture	Silty-Loam (SL)
Cl, %	0.0921		

Figure 3. Soil preparations of the experimental fields

Figure 4. Dividing experimental fields into plots

Figure 5. Spacing between the blocks and between the plots

Figure 6. Herbicide (Treflan) sprays to experimental fields

Figure 7. Fertilizer (DAP) applications to the experimental fields

Figure 8. Arrangement of sowing distances

Figure 9. Random distribution of the experimental plots and irrigation for germination

Figure 10. Germination stages

Figure 11. Application of nitrogen fertilization in two batches

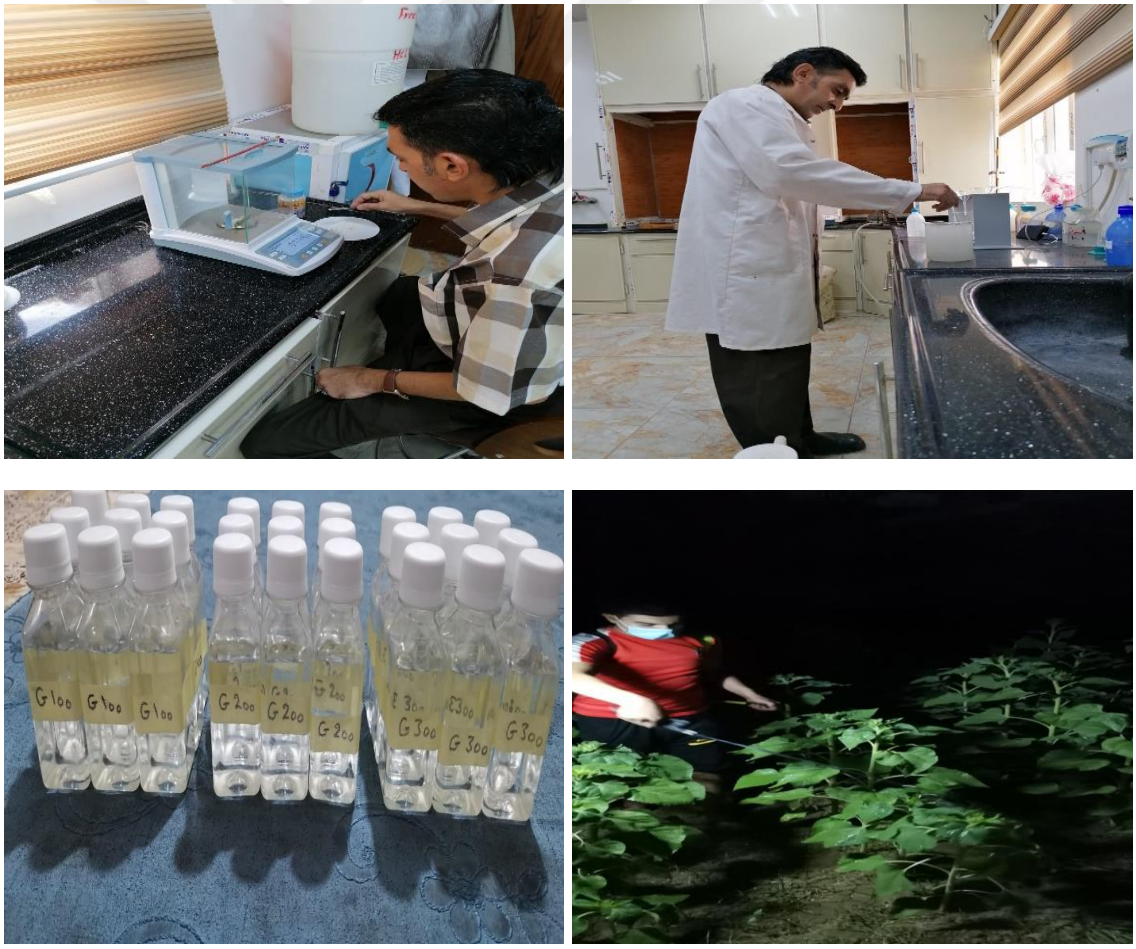


Figure 12. Preparation of glutamic acid solutions and foliar sprays

Figure 13. The other agronomic practices

3.1. Vegetative Growth Parameters

Ten plants were randomly selected from the midlines of each experimental plot to study the following growth parameters at the end of flowering stage.

3.1.1. Stem Height (cm):

Stem heights were measured with the use of a tape measure as the distance between the ground surface and the base of head (Figure 14). Measurements were performed on 10 plants in mid-rows of each plant and average of 10 measurements was taken.

Figure 14. Measurement of stem heigth

3.1.2. Stem Diameter (mm)

Stem diameters were measured with a digital caliper from the mid-section of each plant (Figure 15).

Figure 15. Measurement of stem diameter

3.1.3. Leaf Area (cm^2)

Leaf area was calculated with the use of the following equation (Elsahookie et al., 1982) (Figure 16):

$$LA = 0.65\ \Sigma W2$$

where; LA is the leaf area (cm^2), W2 is the sum of squares of plant leaf width multiplied by the constant of 0.65.

Figure 16. Measurement of leaf area

3.1.4. Leaf area index

Leaf area index was calculated with the use of the following equation:

Leaf area index = Average leaf area of a plant / the area that a plant occupies on the ground.

3.1.5. Chlorophyll Content (%)

A SPAD meter (SPAD 502) was used to measure chlorophyll content of the leaves. Five readings were performed on middle leaves (Figure 17).

Figure 17. Measurement of chlorophyll content

3.1.6. Number of Leaves per Plant (leaf plant^{-1}):

The number of leaves on the stem was counted for ten plants in the flowering stage.

3.1.7. Plant Dry Weight (g plant $^{-1}$):

Five plants were cut from the ground surface, dried naturally in the air and then dried in an oven at 65 °C for 48 hours until a constant mass (Figure 18).

Figure 18. Plant dry weight measurements

3.2. Yield and Yield Components

At full-mature stage of the heads, 10 plants were randomly harvested from the midlines of each plot and the following parameters were measured or calculated:

3.2.1. Seed Yield (t ha^{-1}):

Seed yields were calculated with the use of the following:

Total seed yield = Average plant seed yield x plant density

Resultant values were then converted into yield per hectare (t ha^{-1}).

3.2.2. Number of Seeds per Head (seed head^{-1}):

Number of seeds was counted on 10 plants and average of 10 counts was taken as the number of seeds per head of that plot.

3.2.3. Seed Weight (g plant^{-1}):

The harvested seeds were completely dried and then weighed with the use of a precise scale (±0.01 g).

3.2.4. Head Diameter (cm):

Head diameters were measured from midsection of each head with a tape measure and average of 10 measurements was taken as the head diameter of that plot.

3.2.5. 1000-Seed Weight (g):

The seeds were collected from 10 plant heads of each plot and 1000 seeds were weighed with a precise scale (±0.01 g).

3.2.6. Percentage of Empty Seeds (%):

About 50 g seed sample was taken from each plot, then number of empty and filled seeds was counted and percentage of empty seeds was calculated as: Number of empty seeds / Total number of seeds x 100.

3.2.7. Harvest Index (%):

Harvest index was calculated as: HI = Seed yield / Biological yield x 100

3.2.8. Biological Yield (t ha^{-1}):

Biological yield was calculated as the weight of the entire harvested ten plants (seeds + straw) and converted into yield per hectare (t ha $^{-1}$).

3.2.9. Oil Content (%):

Seeds were ground and placed into a beaker, then supplemented with ethanol and placed into hexane-supplemented Soxhlet extraction device at 37ºC for 12 hours (Chapaman et al., 1961). Following equation was used to calculate oil content of the samples:

Percentage of oil = Weight of oil extracted from seeds / weight of sample seeds x 100

3.2.10. Protein Content (%):

Initially, sample total nitrogen (N) content was determined with the use of micro-kjeldahl method. Resultant N content was then multiplied by a coefficient of 25.6 to get protein content of the samples.

Protein content = Total N x 25.6

CHAPTER FOUR

RESULTS

4.1. Vegetative Growth Parameters

4.1.1. Stem Height (cm):

Table 3 shows the results of the analysis of variance (ANOVA) for stem heights. Significant differences were observed in stem heights of experimental treatments (glutamic acid concentrations and sunflower varieties) at $P \leq 0.05$ level.

Table 3. ANOVA results for stem heights

Source of Variation	Degrees of freedom	Sum of squares	Mean square	F Value
Blocks	2	70.802	35.401	
Varieties (A)	4	1005.416	502.708	25.646
Error A	3	78.407	19.602	
Concentrations (B)	6	1748.083	582.694	465.604
Variety x Concentration	18	999.740	166.623	133.141
Error B	2	22.527	1.251	
Total	35	3854.172		

Mean stem height of the varieties changed between 181.37 - 194.25 cm with the highest value (199.80 cm) from GA300 (300 mg l^{-1}) treatment of V3 (Ishaqi 1) and the lowest value (163.47 cm) from the control GA0 treatment of the same variety (Table 4). Mean stem heights varied with glutamic acid concentrations. The greatest value (198.44 cm) was obtained from GA300 (300 mg l^{-1}) treatments and the lowest value (179.84 cm) was obtained from the control (GA0) treatments.

Table 4. Mean stem heights (cm) of the experimental treatments

Stem Height (cm)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	183.33e	188.40d	185.07e	198.80a	**188.90b**
V2 Aqmar	192.73c	193.80c	193.73c	196.73b	**194.25a**
V3 Ishaqi 1	163.47g	188.27d	173.93f	199.80a	**181.37c**
Mean Con.	**179.84d**	**190.16b**	**184.24c**	**198.44a**	
SE± =	**1.744**				
C. V. =	**5.572**				

4.1.2. Stem Diameter (mm):

Table 5 shows the results of the analysis of variance for stem diameters. Significant differences were observed in stem diameters of the experimental treatments (glutamic acid concentrations and sunflower varieties) at P≤0.05 level.

Table 5. ANOVA results for stem diameters

Source of variation	Degrees of freedom	Sum of squares	Mean square	F Value
Blocks	2	0.152	0.076	
Varieties (A)	4	5.985	2.992	11.346
Error A	3	1.055	0.264	
Concentrations (B)	6	57.267	19.089	80.943
Variety * Concentration	18	14.475	2.413	10.230
Error B	2	4.245	0.236	
Total	35	83.027		

Table 6 shows the mean values for stem diameters. The highest value (25.77 mm) was obtained from the variety V3 (Ishaqi 1) and the lowest value (24.79 mm) was obtained from the variety V1 (Sakha). Differences in stem diameters of V2 (Aqmar) and V3 (Ishaqi 1) were not found to be significant. For interaction of two factors, the highest value (27.67 mm) was obtained from GA300 (300 mg l^{-1}) treatments of variety V1 (Sakha) and the lowest value (23.47 mm) was obtained from the control (GA0) treatments of the same variety.For mean stem diameters at different glutamic acid cocnentrations, the highest value (27.14 mm) was obtained from GA300 (300 mg l^{-1}) treatments and the lowest value (23.81 mm) was obtained from the GA0 (Control) treatments.

Table 6. Mean stem diameters (mm) of the experimental treatments

Stem Diameter (mm)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	23.47f	24.17ef	23.87ef	27.67a	**24.79b**
V2 Aqmar	23.73f	25.90c	25.23cd	27.00ab	**25.47a**
V3 Ishaqi 1	24.23ef	27.37ab	24.70de	26.77b	**25.77a**
Mean Con.	**23.81d**	**25.81b**	**24.60c**	**27.14a**	
SE± =	**0.258**				
C. V. =	**6.114**				

4.1.3. Leaf Area (cm^2):

Table 7 shows the results of the analysis of variance for leaf area. Significant differences were observed in leaf areas of the experimental treatments (glutamic acid concentrations and sunflower varieties) at $P \leq 0.05$ level.

Table 7. ANOVA results for leaf areas (cm^2)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F Value
Blocks	2	31019.847	15509.923	
Varieties (A)	4	11053340.827	5526670.413	54.294
Error A	3	407168.113	101792.028	
Concentrations (B)	6	8785820.916	2928606.972	89.847
Variety x Concentration	18	7372461.911	1228743.652	37.697
Error B	2	586715.993	32595.333	
Total	35	28205507.760		

Table 8 shows that the average leaf areas of the varieties changed between 10188.70 cm^2 - 8847.57 cm^2 with the highest value (10957.33 cm^2) from the GA100 (100 mg l^{-1}) treatments of V2 (Aqmar) and the lowest value (7998.00 cm^2) from the GA0 (Control) treatments of V1 (Sakha). For leaf areas at different glutamic acid concentrations, GA300 (300 mg l^{-1}) treatments yielded a higher average of leaf area (10121.47 cm^2) than the GA0 (Control) treatments (8754.38 cm^2.

Table 8. Mean leaf areas (cm^2) of the experimental treatments

Leaf area (cm^2)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	7998.00i	8334.67h	9185.93f	9871.67cd	**8847.57c**
V2 Aqmar	9637.93de	10957.33a	10181.40c	9978.13c	**10188.70a**
V3 Ishaqi 1	8627.20gh	8716.40g	9491.13fe	10514.60b	**9337.33b**
Mean Con.	**8754.38d**	**9336.13c**	**9619.49b**	**10121.47a**	
SE± =	**148.426**				
C. V. =	**9.447**				

4.1.4. Leaf Area Index (cm^2):

Table 9 shows the results of the analysis of variance for leaf area index values. Significant differences were observed in leaf area index values of the experimental treatments (glutamic acid concentrations and sunflower varieties) at $P \leq 0.05$ level.

Table 9. ANOVA results for leaf area index values (cm^2)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F Value
Blocks	2	0.011	0.005	
Varieties (A)	4	3.604	1.802	54.831
Error A	3	0.131	0.033	
Concentrations (B)	6	2.845	0.948	87.325
Variety x Concentration	18	2.408	0.401	36.950
Error B	2	0.195	0.011	
Total	35	9.183		

There were significant differences in leaf area values of the sunflower varieties (Table 10). The highest value (5.82 cm^2) was obtained from the variety V2 (Aqmar) and the lowest value (5.06 cm^2) was obtained from the variety V1 (Sakha). In terms of leaf area index values of concentration x variety interactions, the highest value (6.26 cm^2) was obtained from GA100 (100 mg l^{-1}) treatments of the variety V2 (Aqmar) and the lowest value (4.57 cm^2) was obtained from GA0 (control) treatments of the variety V1(Sakha). For leaf area index values at different glutamic acid concentrations, the highest value (5.78 cm^2) was obtained from GA300 (300 mg l^{-1}) treatments and and the lowest value (5.00 cm^2) was obtained from the GA0 (Control) treatments.

Table 10. Mean leaf area index values (cm^2) of the experimental treatments

Leaf area index (cm^2)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	4.57i	4.76h	5.25f	5.64cd	**5.06c**
V2 Aqmar	5.51de	6.26a	5.82c	5.70c	**5.82a**
V3 Ishaqi 1	4.93gh	4.98g	5.42ef	6.01b	**5.34b**
Mean Con.	**5.00d**	**5.33c**	**5.50b**	**5.78a**	
SE± =	**0.085**				
C. V. =	**9.435**				

4.1.5. Chlorophyll Content (%):

Table 11 shows the results of the analysis of variance for chlorophyll contents. Significant differences were observed in chlorophyll contents of the experimental treatments (glutamic acid concentrations and sunflower varieties) at P≤0.05 level.

Table 11. ANOVA results for chlorophyll contents (%)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F Value
Blocks	2	2.536	1.268	
Varieties (A)	4	13.496	6.748	6.839
Error A	3	3.947	0.987	
Concentrations (B)	6	17.510	5.837	17.375
Variety x Concentration	18	5.231	0.872	2.595
Error B	2	6.047	0.336	
Total	35	46.230		

In terms of chlorophyll contents of the varieties, the highest value (40.51%) was obtained from the variety V2 (Aqmar) and the lowest value (39.03%) was obtained from the variety V1 (Sakha), with no significant difference between the variety V1 (Sakha) and V3 (Ishaqi 1) (Table 12). There were significant differences in chlorophyll contents of the interactions. The highest value (41.50%) was obtained from GA100 (100 mg l^{-1}) treatments of the variety V2 (Aqmar) and the lowest value (37.73%) was obtained from GA0 (control) treatments of the variety V1 (Sakha). Differences in chlorophyll contents of glutamic acid concentrations were not found to be significant. The highest value (40.38%) was obtained from GA100 (100 mg l^{-1}) treatments and the lowest value (38.53%) was obtained from GA0 (control) treatments.

Table 12. Mean chlorophyll contents (%) of the experimental treatments

Chlorophyll Content (%)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	37.73f	39.57cde	38.83e	39.97bcd	**39.03b**
V2 Aqmar	39.23de	41.50a	40.57abc	40.73ab	**40.51a**
V3 Ishaqi 1	38.63ef	40.07bcd	40.43abc	39.17de	**39.58b**
Mean Con.	**38.53b**	**40.38a**	**39.94a**	**39.96a**	
SE± =	**0.194**				
C. V. =	**2.935**				

4.1.6. Number of Leaves per Plant (leaf plant^{-1}):

Table 13 shows the results of the analysis of variance for number of leaves per plant. There were significant differences in number of leaves per plant of glutamic acid concentrations ($P \leq 0.05$), but no significant differences were seen in chlorophyll contents of the varieties.

Table 13. ANOVA results for number of leaves per plant (leaf plant $^{-1}$)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F Value
Blocks	2	0.176	0.088	
Varieties (A)	4	1.109	0.554	0.999
Error A	3	2.220	0.555	
Concentrations (B)	6	3.186	1.062	9.219
Variety x Concentration	18	0.731	0.122	1.058
Error B	2	2.073	0.115	
Total	35	9.319		

Differences in number of leaves per plant of the varieties were not found to be significant (Table 14). The greatest value (23.93 leaf plant^{-1}) was obtained from the variety V2 (Aqmar) and the lowest value (23.52 leaf.plant^{-1}) was obtained from the variety V3 (Ishaqi1). There were significant differences in number of leaves per plant of the interactions. The greatest value (24.33 leaf plant^{-1}) was obtained from GA300 (300 mg l^{-1}) treatments of the variety V2 (Aqmar) and the lowest value (22.93 leaf plant^{-1}) was obtained from GA0 (Control) treatments of the variety V3 (Ishaqi1). 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 GA300 (300 mg l^{-1}) treatments and the lowest value (23.22 leaf plant^{-1}) was obtained from GA0 (Control) treatments.

Table 14. Mean number of leaves per plant (leaf plant ^{1}) of the experimental treatments

Number of Leaves in Plant (leaf plant ^{1})					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	23.13cd	23.60bc	23.73abc	24.07ab	**23.63a**
V2 Aqmar	23.60bc	23.80ab	24.00ab	24.33a	**23.93a**
V3 Ishaqi 1	22.93d	23.93ab	23.47bcd	23.73abc	**23.52a**
Mean Con.	**23.22b**	**23.78a**	**23.73a**	**24.04a**	
SE± =	**0.087**				
C. V. =	**2.208**				

4.1.7. Plant Dry Weight (g plant^{-1}):

Table 15 shows the results of the analysis of variance for plant dry weights. Significant differences were observed in plant dry weights of the experimental treatments (glutamic acid concentrations and sunflower varieties) at P≤0.05 level.

Table 15. ANOVA results for plant dry weights (g plant ^{1})

Source of variation	**Degrees of freedom**	**Sum of squares**	**Mean square**	**F Value**
Blocks	2	47.362	23.681	
Varieties (A)	4	8391.482	4195.741	109.023
Error A	3	153.940	38.485	
Concentrations (B)	6	7272.777	2424.259	119.625
Variety x Concentration	18	2673.033	445.506	21.983
Error B	2	364.780	20.266	
Total	35	18856.012		

In terms of plant dry weights of the varieties, the highest value (181.22 g plant^{-1}) was obtained from the variety V2 (Aqmar) and the lowest value (144.83 g plant^{-1}) was obtained from the variety V1 (Sakha) (Table 16). In terms of plant dry weights of interactions, thehighest value (199.93 g plant^{-1}) was obtained from the GA100 (100 mg

l^{-1}) treatments of the variety V2 (Aqmar) and the lowest value (130.60 g $plant^{-1}$) was obtained from the GA0 (Control) treatmetns of the variety V1 (Sakha).For plant dry value weights of the glutamic acid concentrations, the highest (182.38 g $plant^{-1}$) was obtained from GA300 (300 mg l^{-1}) treatments and the lowest value (143.09 g $plant^{-1}$) was obtained from the GA0 (Control) treatments.

Table 16. Mean plant dry weights (g $plant^{-1}$) of the experimental treatments

Dry weight (g $plant^{-1}$)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	130.60g	143.33f	137.80fg	167.60cd	**144.83c**
V2 Aqmar	161.73de	199.93a	170.87c	192.33ab	**181.22a**
V3 Ishaqi 1	136.93fg	140.40f	157.60e	187.20b	**155.53b**
Mean Con.	**143.09d**	**161.22b**	**155.42c**	**182.38a**	
SE± =	**3.808**				
C. V. =	**14.315**				

4.2. Yield and Yield Components

4.2.1. Seed Yield (t ha^{-1})

Table 17 shows the results of the analysis of variance for seed yields. Significant differences were observed in seed yields of the experimental treatments (glutamic acid concentrations and sunflower varieties) at P≤0.05 level.

Table 17. ANOVA results for seed yields (t ha^{-1})

Source of variation	**Degrees of freedom**	**Sum of squares**	**Mean square**	**F Value**
Blocks	2	0.152	0.076	
Varieties (A)	4	0.198	0.099	1.300
Error A	3	0.305	0.076	
Concentrations (B)	6	18.962	6.321	327.991
Variety x Concentration	18	1.265	0.211	10.940
Error B	2	0.347	0.019	
Total	35	21.077		

There were no significant differences in seed yields of the sunflower varieties (Table 18). The highest value (4.87 t ha^{-1}) was obtained from the variety V2 (Aqmar) and the lowest value (4.69 t ha^{-1}) was obtained from the variety V3 (Ishaqi1). Interactions had significant effects on seed yields. The highest value (5.49 t ha^{-1}) was obtained from GA300 (300 mg l^{-1}) treatments of the variety V3 (Ishaqi 1) and the lowest value (3.23 t ha^{-1}) was obtained from GA0 (control) treatments of the variety V1 (Sakha). There were significant differences in seed yields of glutamic acid concentrations. The highest value (5.29 t ha^{-1}) was obtained from GA300 (300 mg l^{-1}) treatments and the lowest value (3.53 t ha^{-1}) was obtained from GA0 (control) treatments. There were no significant differences in seed yields of GA100 and GA200 treatments.

Table 18. Mean seed yields (t ha^{-1}) of the experimental treatments

Seed Yield (t ha^{-1})					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	3.23f	5.33ab	5.30ab	5.26ab	**4.78a**
V2 Aqmar	3.91e	5.23ab	5.19bc	5.13bc	**4.87a**
V3 Ishaqi 1	3.43f	4.86d	4.97cd	5.49a	**4.69a**
Mean Con.	**3.53c**	**5.14b**	**5.15b**	**5.29a**	
SE± =	**0.130**				
C. V. =	**16.386**				

4.2.2. Number of Seeds per Head (seed $head^{-1}$):

Table 19 shows the results of the analysis of variance for the number of seeds per head. There were significant differences in number of seeds per head of the experimental treatments (glutamic acid concentrations and sunflower varieties) at P≤0.05 level.

Table 19. ANOVA results for number of seeds per head (seed $head^{-1}$)

Source of variation	**Degrees of freedom**	**Sum of squares**	**Mean square**	**F Value**
Blocks	2	1988.667	994.333	
Varieties (A)	4	5846.167	2923.083	2.207
Error A	3	5296.833	1324.208	
Concentrations (B)	6	208693.194	69564.398	74.831
Variety x Concentration	18	20963.389	3493.898	3.758
Error B	2	16733.167	929.620	
Total	35	257532.750		

There were no significant differences in number of seed per head of the sunflower varieties (Table 20). The highest value (850.83 seeds head^{-1}) was obtained from the variety V3 (Ishaqi 1) and the lowest value (819.67 seed head^{-1}) was obtained from the variety V1 (Sakha). In terms of the number of seeds per head of interactions, the highest value (924.33 seed head^{-1}) was obtained from GA300 (300 mg l^{-1}) treatments of the variety V3 (Ishaqi 1) and the lowest value (675.33 seed head^{-1}) was obtained from GA0 (control) treatments of the variety V1 (Sakha). For the number of seeds per head of glutamic acid concentrations, the highest value (908.44 seed head^{-1}) was obtained from GA100 (100 mg l^{-1}) treatments and the lowest value (710.89 seed head^{-1}) was obtained from the GA0 (control) treatments. There was no significant difference between GA100 and GA300 concentrations.

Table 20. Mean number of seeds per head (seed head^{-1}) of the experimental treatments

Number of Seeds per Head (seed head^{-1})					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	675.33f	898.33ab	826.33cd	878.67abc	**819.67a**
V2 Aqmar	762.00e	912.33a	812.00de	848.67bcd	**833.75a**
V3 Ishaqi 1	695.33f	914.67a	869.00abc	924.33a	**850.83a**
Mean Con.	**710.89c**	**908.44a**	**835.78b**	**883.89a**	
SE± =	**14.211**				
C. V. =	**10.250**				

4.2.3. Seed Weight (g plant $^{-1}$)

Table 21 shows the results of the analysis of variance for seed weights. There were significant differences in seed weights of the experimental treatments (glutamic acid concentrations and sunflower varieties) at P≤0.05 level.

Table 21. ANOVA results for seed weights (g plant $^{-1}$)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F Value
Blocks	2	26.000	13.000	
Varieties (A)	2	11.167	5.583	0.590
Error A	4	37.833	9.458	
Concentrations (B)	3	1953.639	651.213	330.192
Variety x Concentration	6	134.611	22.435	11.376
Error B	18	35.500	1.972	
Total	35	2172.750		

There were no significant differences in seed weights of the sunflower varieties (Table 22). The highest value (49.17 g plant^{-1}) was obtained from the variety V2 (Aqmar) and the lowest value (47.83 g plant^{-1}) was obtained from the variety V3 (Ishaqi 1). There were significant differences in seed weights of interactions. The highest value (56.00 g plant^{-1}) was obtained from GA300 (300 mg l^{-1}) treatments of the variety V3 (Ishaqi1) and the lowest value (33.00 g plant^{-1}) was obtained from GA0 (Control) treatments of the variety V1 (Sakha). There were significant differences in seed yields of glutamic acid concentrations. The greatest value (54.00 g plant^{-1}) was obtained from GA300 (300 mg l^{-1}) treatments and the lowest value (35.89 g plant^{-1}) was obtained from GA0 (control) treatments. There was no significant difference between GA100 and GA200 concentrations.

Table 22. Mean seed weights (g plant^{-1}) of the experimental treatments

Seed Weights (g plant^{-1})					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	33.00g	54.33ab	54.00ab	53.67abc	**48.75a**
V2 Aqmar	39.67f	53.33bc	51.33cde	52.33bcd	**49.17a**
V3 Ishaqi 1	35.00g	49.67e	50.67de	56.00a	**47.83a**
Mean Con.	**35.89c**	**52.44b**	**52.00b**	**54.00a**	
SE± =	**1.319**				
C. V. =	**16.355**				

4.2.4. Head Diameter (cm)

Table 23 shows the results of the analysis of variance for head diameters. There were significant differences in head diameters of the experimental treatments (glutamic acid concentration and sunflower varieties) at P≤0.05 level.

Table 23. ANOVA results for head diameters (cm)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F Value
Blocks	2	0.755	0.378	
Varieties (A)	2	0.380	0.190	0.358
Error A	4	2.125	0.531	
Concentrations (B)	3	11.014	3.671	22.619
Variety x Concentration	6	3.827	0.638	3.929
Error B	18	2.922	0.162	
Total	35	20.268		

There were no significant differences in head diameters of the sunflower varieties (Table 24). The highest value (17.525 cm) was obtained from the variety V2 (Aqmar) and the lowest value (17.275 cm) was obtained from the variety V3 (Ishaqi 1). Interactions had significant effects on head diameters. The highest value (18.567 cm) was obtained from GA100 (100 mg l^{-1}) treatments of the variety V2 (Aqmar) and the lowest value (16.333 cm) was obtained from GA0 (Control) treatments of the variety V3 (Ishaqi1). There are significant differences in head diameters of glutamic acid concentrations. The greatest value (17.944 cm) was obtained from the GA100 (100 mg l^{-1}) treatments and the lowest value (16.478 cm) was obtained from the GA0 (Control) treatments. There were no significant differences between GA200 and GA300 concentrations.

Table 24. Mean head diameters (cm) of the experimental treatments

Head Diameter (cm.plant^{-1})					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	16.57d	17.40bc	18.03ab	17.50bc	**17.38a**
V2 Aqmar	16.53d	18.57a	17.43bc	17.57bc	**17.53a**
V3 Ishaqi 1	16.33d	17.87ab	16.97cd	17.93ab	**17.28a**
Mean Con.	**16.48c**	**17.94a**	**17.48b**	**17.67ab**	
SE± =	**0.127**				
C. V. =	**4.402**				

4.2.5. 1000-Seed Weight (g)

Table 25 shows the results of the analysis of variance for 1000-seed weights. There were significant differences in 1000-seed weights of the experimental treatments (glutamic acid concentrations and sunflower varieties) at P≤0.05 level.

Table 25. ANOVA results for 1000 seed weights (g)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F Value
Blocks	2	6.889	3.444	
Varieties (A)	4	6.056	3.028	0.686
Error A	3	17.667	4.417	
Concentrations (B)	6	582.306	194.102	31.288
Variety x Concentration	18	191.278	31.880	5.139
Error B	2	111.667	6.204	
Total	35	908.972		

There were no significant differences in 1000-seed weights of the sunflower varieties (Table 26). The highest value (66.50 g) was obtained from the variety V1 (Sakha) and the lowest value (65.50 g) was obtained from the variety V2 (Aqmar). Interactions had significant effects on 1000-seed weights. The highest value (70.67 g) was obtained from GA200 (200 mg l^{-1}) treatments of the variety V2 (Aqmar) and the lowest value (55.00 g) was obtained from GA0 (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 GA100 (100 mg l^{-1}) treatments and the lowest value (59.11 g) was obtained from the GA0 (control) treatments. There were no significant differences between GA200 and GA300 treatments.

Table 26. Mean 1000-seed weights (g) of the experimental treatments

1000-Seed Weight (g)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	64.67b	66.67ab	66.67ab	68.00ab	**66.50a**
V2 Aqmar	55.00c	69.67a	70.67a	66.67ab	**65.50a**
V3 Ishaqi 1	57.67c	70.00a	68.67ab	68.00ab	**66.08a**
Mean Con.	**59.11b**	**68.78a**	**68.67a**	**67.56a**	
SE± =	**0.861**				
C. V. =	**7.830**				

4.2.6. Percentage of Empty Seeds (%)

Table 27 shows the results of the analysis of variance for percentage of empty seeds. There were significant differences in percentage of empty seeds of the experimental treatments (glutamic acid concentrations and sunflower varieties) at P≤0.05 level.

Table 27. ANOVA results for percentage of empty seeds

Source of variation	Degrees of freedom	Sum of squares	Mean square	F Value
Blocks	2	2.553	1.276	
Varieties (A)	4	3.631	1.815	0.807
Error A	3	8.995	2.249	
Concentrations (B)	6	436.690	145.563	292.360
Variety x Concentration	18	109.775	18.296	36.747
Error B	2	8.962	0.498	
Total	35	568.052		

Table 28 shows that there were no significant differences in percentage of empty seeds of the varieties. The highest value (75.29%) was obtained from the variety V3 (Ishaqi 1) and the lowest value (74.52%) was obtained from the variety V2 (Aqmar). Interactions had significant effects on percentage of empty seeds. The greatest value (80.26%) was obtained from GA200 (200 mg l^{-1}) treatments of the variety V1 (Sakha) and the lowest value (66.10%) was obtained GA0 (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 GA200 (200 mg l^{-1}) treatments and lowest value (62.24%) was obtained from the GA0 (Control) treatments. There were no significant differences between GA200 and GA300 treatments.

Table 28. Mean percentage of empty seeds of the experimental treatments

Percentage of Empty Seeds (%)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	66.10h	75.56d	80.26a	78.05bc	**74.99a**
V2 Aqmar	72.08f	73.99e	74.48de	77.51c	**74.52a**
V3 Ishaqi 1	69.52g	75.34d	78.85b	77.45c	**75.29a**
Mean Con.	**69.24c**	**74.96b**	**77.86a**	**77.67a**	
SE± =	**0.678**				
C. V. =	**5.432**				

4.2.7. Harvest Index (%):

Table 29 shows the results of the analysis of variance for the harvest index. There were significant differences in harvest index values of the experimental treatments (glutamic acid concentrations and sunflower varieties) at P≤0.05 level.

Table 29. ANOVA results for harvest index (%)

Source of variation	Degrees of freedom	Sum of squares	Mean square	F Value
Blocks	2	5.803	2.901	
Varieties (A)	4	240.653	120.327	32.251
Error A	3	14.924	3.731	
Concentrations (B)	6	370.887	123.629	105.374
Variety x Concentration	18	133.254	22.209	18.930
Error B	2	21.118	1.173	
Total	35	780.837		

For harvest index of sunflower varieties, the highest value (33.58%) was obtained from the variety V1 (Sakha) and the lowest value (27.28%) was obtained from the variety V2 (Aqmar) (Table 30). There were significant differences in harvest index values of the interactions. The highest value (38.73%) was obtained from GA200 (200 mg l^{-1}) treatments of the variety V1 (Sakha) and the lowest value (25.59%) was obtained from GA0 (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 GA100 (100 mg l^{-1}) treatments and the lowest value (25.81%) was obtained from the GA0 (Control) treatments. There were no significant differences between GA100 and GA200 treatments.

Table 30. Mean harvest index (%) values of the experimental treatments

Harvest Index (%)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	25.59f	37.91a	38.73a	32.08c	**33.58a**
V2 Aqmar	26.10f	27.34ef	28.88de	26.81f	**27.28c**
V3 Ishaqi 1	25.74f	35.50b	32.89c	29.97d	**31.03b**
Mean Con.	**25.81c**	**33.59a**	**33.50a**	**29.62b**	
SE± =	**0.796**				
C. V. =	**15.570**				

4.2.8. Biological Yield (t ha^{-1})

Table 31 shows the results of the analysis of variance for biological index. There were significant differences in biological yields of the experimental treatments (glutamic acid concentrations and sunflower varieties) at P≤0.05 level.

Table 31. ANOVA results for biological yield (t ha^{-1})

Source of variation	Degrees of freedom	Sum of squares	Mean square	F Value
Blocks	2	1.419	0.709	
Varieties (A)	4	90.420	45.210	51.219
Error A	3	3.531	0.883	
Concentrations (B)	6	83.217	27.739	202.761
Variety x Concentration	18	19.822	3.304	24.149
Error B	2	2.463	0.137	
Total	35	199.453		

For biological yields of the varieties, the highest value (17.98 t ha^{-1}) was obtained from the variety V2 (Aqmar) and the lowest value (14.23 t ha^{-1}) was obtained from the variety V1 (Sakha) (Table 32). There were significant differences in biological yields of the interactions. The greatest value (19.08 t ha^{-1}) was obtained from GA300 (300 mg l^{-1}) treatments of the variety V2 (Aqmar) and the lowest value (12.66 t ha^{-1}) was obtained from GA0 (control) treatments of the variety V1 (Sakha). In terms of biological yields of different glutamic acid concentrations, the highest value (17.96 t ha^{-1}) was obtained from the GA300 (300 mg L^{-1}) treatments and the lowest value (13.69 t ha^{-1}) was obtained from the GA0 (control) treatments.

Table 32. Mean biological yields (t ha^{-1}) of the experimental treatments

Biological Yield (t ha^{-1})					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 Sakha	12.66g	14.09e	13.72ef	16.46c	**14.23c**
V2 Aqmar	15.12d	18.72ab	18.98ab	19.08a	**17.98a**
V3 Ishaqi 1	13.30fg	13.71ef	15.53d	18.33b	**15.22b**
Mean Con.	**13.69d**	**15.51c**	**16.07b**	**17.96a**	
SE± =	**0.393**				
C. V. =	**15.012**				

4.2.9. Oil Content (%):

Table 33 shows the results of the analysis of variance for oil content. There were significant differences in oil contents of the experimental treatments (glutamic acid concentrations and sunflower varieties) at P≤0.05 level.

Table 33. ANOVA results for oil content ***(%)***

Source of variation	Degrees of freedom	Sum of squares	Mean square	F Value
Blocks	2	1.728	0.864	
Varieties (A)	4	4.564	2.282	3.166
Error A	3	2.883	0.721	
Concentrations (B)	6	209.503	69.834	68.595
Variety x Concentration	18	63.874	10.646	10.457
Error B	2	18.325	1.018	
Total	35	299.149		

Table 34 shows that there were significant differences in oil contents of the sunflower varieties. The highest value (44.09%) was obtained from the variety V1 (Sakha) and the lowest value (43.23%) was obtained from the variety V3 (Ishaqi 1). The differences between the variety V2 (Aqmar) and V3 (Ishaqi 1) were not found to be significant. Interactions had also significant effects on oil contents. The greatest value (48.05%) was obtained from GA200 (200 mg l^{-1}) treatments of the variety V3 (Ishaqi 1) and the lowest value (38.23%) was obtained from GA0 (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 GA200 (200 mg l^{-1}) treatments and the lowest value (39.98%) was obtained from the GA0 (control) treatments. There were no significant differences between GA100 and GA300 treatments.

Table 34. Mean oil contents (%) of the experimental treatments

Oil Content (%)					
Varieties	**Glutamic Acid Concentrations**				**Mean Var.**
	GA 0	**GA 100**	**GA 200**	**GA 300**	
V1 sakha	41.96d	45.55b	44.60bc	44.26bc	**44.09a**
V2 Aqmar	39.75e	42.25d	47.49a	45.62b	**43.78ab**
V3 Ishaqi 1	38.23e	43.64cd	48.05a	43.00cd	**43.23b**
Mean Con.	**39.98c**	**43.81b**	**46.71a**	**44.29b**	
SE± =	**0.494**				
C. V. =	**6.788**				

4.2.10. Protein Content (%):

Table 35 shows the results of the analysis of variance for protein content. There were significant differences in protein contents of the experimental treatments (glutamic acid concentrations and sunflower varieties) at P≤0.05 level.

Table 35. ANOVA results for protein content ***(%)***

Source of variation	Degrees of freedom	Sum of squares	Mean square	F Value
Blocks	2	1.495	0.748	
Varieties (A)	4	4.838	2.419	3.436
Error A	3	2.816	0.704	
Concentrations (B)	6	57.668	19.223	24.703
Variety x Concentration	18	14.057	2.343	3.011
Error B	2	14.007	0.778	
Total	35	93.386		

For protein contents of the varieties, the highest value (15.51%) was obtained from the variety V3 (Ishaqi 1) and the lowest value (14.63%) was obtained from the variety V2 (Aqmar). There was no significant difference between the variety V1 (Sakha) and V2 (Aqmar) and between the variety V1 and V3. Interactions had significant effects on protein contents. The greatest value (18.22%) was obtained from GA100 (100 mg l^{-1}) treatments of the variety V3 (Ishaqi 1) and the lowest value (13.31%) was obtained from GA0 (control) treatments of the variety V2 (Aqmar). There were significant differences in oil contents of different glutamic acid concentrations. The greatest value (16.51%) was obtained from the GA100 (100 mg l^{-1}) treatments and the lowest value (13.57%) was obtained from the GA0 (control) treatments. There was no significant difference between GA0 and GA200 treatments and between GA100 and GA300 treatments.

Table 36. Mean protein contents (%) ***of the experimental treatments***

Varieties	Protein Content (%)				Mean Var.
	Glutamic Acid Concentrations				
	GA 0	GA 100	GA 200	GA 300	
V1 Sakha	13.63d	15.73bc	14.23cd	17.28ab	**15.22ab**
V2 Aqmar	13.31d	15.59c	13.95d	15.68bc	**14.63b**
V3 Ishaqi 1	13.77d	18.22a	14.39cd	15.68bc	**15.51a**
Mean Con.	**13.57b**	**16.51a**	**14.19b**	**16.21a**	
SE± =	**0.276**				
C. V. =	**10.933**				

CHAPTER FIVE

DISCUSSION AND CONCLUSION

5.1. Vegetative Growth Parameters

5.1.1. Stem Height (cm)

Present 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 V2 (Aqmar). Stem heights increased with increasing glutamic acid concentrations. Atiyah et al. (2017) and Ali et al. (2007) 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 GA300 (300 mg l^{-1}) treatments. Hamed et al. (2016) 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. Al-Bahadli et al. (2016) 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.

5.1.2. Stem Diameter (mm)

Present stem diameters also significantly varied with the experimental treatments (glutamic acid concentrations and sunflower varieties). El-Hawary et al. (2019) investigated the effects of ascorbic and salicylic acid treatments on growth parameters of maize plants and reported that amino acid treatments increased cell division and

carbon metabolism and consequently increased the rate of plant growth and stem diameter. Adeem et al. (2017) also reported increasing stem diameters of maize plants with amino acid treatments.

Significant differences were also observed in stem diameters obtained at different glutamic acid concentrations. Zewail et al. (2014) investigated the effects of seaweed extract and amino acid treatments on growth parameters and vital components of common bean (Phaseolus vulgaris. L) products and reported significant effects of the experimental treatments of plant growth parameters. Similarly, Sadak et al. (2015) mentioned about positive effects of amino acid treatments on plant growth parameters. Hildebrandt et al (2015) studied the effects of amino acid treatments on plant growth and reported that amino acid treatments increased photosynthetic pigments and uptake of mineral nutrients, which in turn led to an increase in plant growth and stem diameters. Present findings on stem diameters well-comply with the results of those previous studies.

5.1.3. Leaf Area (cm^2)

There were significant differences in leaf areas of the sunflower varieties mostly because of genetic structures of the varieties. Genetic capabilities and acidic nature of nutrients required for plant growth and development reflected as an increase in leaf area (Atiyah et al., 2017). Ayas & Gulser et al. (2005) sprayed sunflower plants with nutrient solutions and reported thay nutrient sprays increased leaf area. Significant differences were seen in leaf areas obtained at different glutamic acid concentrations, because amino acids stimulate growth through cell elongation and division and regulate the source of nutrients. Consitent with the present findings, Kalaf et al. (2020) reported significant increases in leaf areas with amino acid treatments. Ghassemi-Golezani et al. (2018) reported a significant increase in leaf area of soybean plant with salicylic and jasmonic acid treatments.

5.1.4. Leaf Area Index

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 et al. (2017) also reported different leaf area and thus leaf area index values for

different sunflower varieties. Abdel Latef & Tran et al. (2016) reported that amino acid treatments had significant effects on growth parameters of maize plants, increased the production of soluble proteins, total free amino acids and proline, thus improved plant growth through enhancing photosynthetic activaty and antioxidant mechanisms. There were significant differences in leaf area index values obtained at different glutamic acid concentrations. Adeem et al. (2017) also reported increasing leaf area index values with amino acid treatments. Consistent with the present findings, El-Hawary et al. (2019) reported significant effects of ascorbic and salicylic acid treatments on growth parameters of maize plants.

5.1.5. Chlorophyll Content (%)

Statistical analyses revealed that there were significant differences in chlorophyll contents pf the sunflower varieties, since amino acid sprays reduced the harmful effects of stress factors and increased photosynthetic pigments (Mervat Sadak & Mostafa et al., 2015). Consistent with the present findings, Yan et al. (2011) indicated that proline treatments improved 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-Kaisi et al., 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.

5.1.6. Number of Leaves per Plant (leaf plant^{-1})

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 varities had the same effect on number of leaves per plant trait of the varieties (Pinheiro et al., 2011). 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 (Majid & Al-Bahadli et al., 2016). Complying with the present findings on number of leaves per plant, Al-Kaisi et al.

(2016) 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.

5.1.7. Plant Dry Weight (g)

Present findings revealed that there were significant differences in plant dry weights of the sunflower varieties and the reason might be the difference in the genetic structures of the varities. Foliar sprays of amino acids play a significant positive role as a nutrient for plant growth and development, in addition to its role as an anti-osmosis factor (Sadak & Mostafa et al., 2015). There were also significant differences in plant dry weights obtained at different glutamic acid concentrations, since external amino acid treatments led to improved vegetative growth parameters, positively reflected as an increase in plant dry weights (Kalaf et al., 2020). Similarly, Al-Tamimi et al. (2015) reported that proline and salicylic acid treatments increased plant growth parameters of sunflower plants, increased plant's ability to photosynthesis by controlling the opening and closing of stomata as well as the plant's ability to build chlorophyll pigments and regulated transpiration process.

5.2. Yield Components

5.2.1. 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 (Alsubaihi et al., 2020). 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 (Hamed et al., 2016). Present findings on seed yields were consistent with the results of Khan et al. (2015) indicating an important role of salicylic acid in bearing abiotic stresses in plants.

5.2.2. Number of Seeds per Head (seed head^{-1})

Statistical analyses 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. It contributed significantly to increasing the processing of new growth sites (flowers) with growth requirements and thus reducing abortion and increasing numbers (Zohaib et al., 2018). There were also significant differences in number of seeds per head obtained at different glutamic acid concentrations. Amino acid sprays improved photosynthesis and transport of nutrients to the center of the cells and thus increased the yield of seeds in the head and this analysis was consistent with what was mentioned by Zewail et al. (2014) in his trials by applying amino acids to a soybean plant as well as with Sadak & Mostafa et al. (2015) in his study of the physiological changes of a soybean plant after application of amino acids to the plant.

5.2.3. Seed Weight (g plant^{-1})

Present 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 & Mostafa et al. (2015) and Sadak et al. (2014) reported significant effects of ascorbic acid treatments on phenotypic traits, yield and yield components of flax plants. 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 (Alsubaihi et al., 2020). Present findings were consistent with the results of Al-Bahadli et al. (2016) indicating significant effects of proline treatments on growth parameters of the sunflower plants.

5.2.4. Head Diameter (cm)

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. Al-Bahadli et al (2016) reported positive effects of amino acid treatments on carbohydrate production and consequently on vegetative growth and fruit growth. Al-Bahadli et al. (2015) indicated sunflower crop response to proline treatments during different irrigation periods. Present findings on head diameters are consistent with the findings of Alak et al. (2016) indicating the role of proline in improving the yield and yield components of sunflower under water stress conditions.

5.2.5. 1000-Seed Weight (g)

Present statistical analyses 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. Al-Bahadli et al. (2016) reported significant effects of proline treatments on seed yields and 1000-seed weights. Alak et al. (2010) 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 (Sadak & Mostafa et al., 2015).

5.2.6. Percentage of Empty Seeds (%)

Present 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 et al. (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 et al. (2016) indicating the role of proline in improving yield and yield components of sunflower under water stress conditions.

5.2.7. 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 (Hamed et al., 2016). Present findings on harvest index are consistent with the findings of Hegazi et al (2007) reporting positive impacts of salicylic acid treatments on yield components of soybean plants.

5.2.8. Biological Yield (t ha^{-1})

Statistical analyses 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 (Alsubaihi et al., 2020). There were significant differences also in biological yields obtained at different glutamic acid concentrations. The reason may be due to the role of glutamic acid in improving most of the physiological processes such as stimulating radicals to absorb, increasing division, lengthening cells, encouraging enzyme activity, especially antioxidant enzymes, all resulting in increased biological yield (Talib et al., 2017). Present findings on biological yields are consistent with the findings of Alak et al. (2016) 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 (Khan et al. 2015). Present findings of biological yields are also consistent with the findings of Al-Bahadli et al. (2015) indicating positive effects of proline treatments on biological yields of sunflower (*Helianthus annuus* L.) plants.

5.2.9. Oil Content (%)

Statistical analysis tables 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 et al, 2016). This result is consistent with what Al-Bahadli et al (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 et al. (2016) indicating significant effects of salicylic acid treatments on oil content of safflower plants.

5.2.10. Protein Content (%)

Present 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 feeding 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 & Nair, 2015). Al - Seedi et al. (2015) indicated that increasing acid concentrations encouraged the absorption of the basic elements for building proteins (sulfur, phosphorous and nitrogen) and the activity of some enzymes to build a protein. Raskin et al. (1992) and Webber (2002) also

indicated that acid treatments promoted the formation of proteins and some other compounds effective in inhibition of the activity of proteolytic enzymes such as proteases and peptidases.

CONCLUSION

The present thesis was conducted to determine the effects of foliar glutamic acid treatments at different doses on yield and growth parameters of three different sunflower varieties. The primary objective was to determine the effects of glutamic acid treatments on phenotypic traits, growth parameters, yield and yield components and to determine the best concentration that can be applied to get the highest values of the studied traits. Experiments were conducted in randomized blocks split-plots experimental design with three replications. There were 36 plots (3 varieties x 4 concentrations x 3 replicates). Glutamic acid concentrations (0, 100, 200 and 300 mg l^{-1}) were placed into sub-plots and sunflower varieties (V1 (Sakha), V2 (Aqmar) and V3 (Ishaqi1)) were placed into the main plots. In this study, the correct agricultural processes were followed accurately, including land preparation, fertilization, and irrigation, according to the study plan followed, taking into account the specific timings for each agricultural operation performed on the plant. After germination, integrated growth, head formation and ripening readings were taken for the set of traits to be studied and analyzed graphically. For the factor of variety, the best results were obtained from the variety V2 (Aqmar), where it was significantly superior in most of the studied traits (stem height, leaf area, number of leaves per plant, leaf area index, chlorophyll content, seed yield, seed weight, head diameter and biological yield). On the other hand, for the factor of glutamic acid concentrations, the best results were obtained from GA300 (300 mg l^{-1}) treatments, which was significantly superior in most of the studied traits (stem height, stem diameter, number of leaves per plant, leaf area, leaf area index, plant dry weight, seed yield, seed weight and biological yield). For interactions (varieties x concentrations), the best results were obtained from GA300 (300 mg l^{-1}) treatments of the variety V3 (Ishaqi1), which was significantly superior in some traits (stem height, plant dry weight, seed yield, number of seeds per head and seed weight). However, GA100 (100 mg l^{-1}) treatments of the variety V2 (Aqmar) were

also significantly superior in most of the studied traits (leaf area index, chlorophyll content, number of leaves per plant and head diameter); GA200 (200 mg l^{-1}) treatments of the variety V3 (Ishaqi) was superior in oil content and finally GA100 (100 mg l^{-1}) treatments of the variety V3 (Ishaqi) was superior in protein content.

The difference in the genetic structures of the varieties and their interactions with the amino acid concentrations had an important role in identification of superior traits.

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