Journal homepage
www.ajas.uoanbar.edu.iq
Anbar Journal of Agricultural Sciences
(University of Anbar – College of Agriculture)

VARIATIONS IN GROWTH, YIELD, AND ANATOMY OF THREE VARIETIES OF SOYBEANS (GLYCINE MAX L. – FABACEAE)

Y. A. Al-Janabi [1] **A. Ch. Al-Fahad** [1] **M. A. Al-Hadeethi** [2]*
P. Sutthisaksopon [3] **H. Kh. Rahman** [2]

[1] **Department of Field Crops College of Agriculture, University of Anbar**
[2] **Department of Biology, College of Education for Pure Sciences Ibn Al-Haitham, University of Baghdad**
[3] **Faculty of Environmental Culture and Ecotourism, Srinakharinwirot University, Bangkok, Thailand**

***Correspondence to:** M. A. H. Al-Hadeethi, Department of Biology, College of Education for Pure Sciences Ibn Al-Haitham, University of Baghdad, Iraq.
Email: muazaz.a.h@ihcoedu.uobaghdad.edu.iq

Article info

Received: 2024-07-11
Accepted: 2024-08-16
Published: 2024-12-31

DOI-Crossref:
10.32649/ajas.2024.184462

Cite as:
Al-Janabi, Y. A., Al-Fahad, A. Ch., Al-Hadeethi, M. A., Sutthisaksopon, P., and Rahman, H. Kh. (2024). Variations in growth, yield, and anatomy of three varieties of soybeans (glycine max l. – fabaceae). Anbar Journal of Agricultural Sciences, 22(2): 882-897.

Abstract

This study was conducted in the fields of Abu-Ghraib City in Baghdad during the summer of 2022 by applying a RCBD in a split-plate arrangement with three replications. The study included two factors, the first represented glutathione concentrations of 0, 75, 150, and 225 mg L^{-1}, and the second included three soybean varieties (Giza 82, Giza 83, and Giza 35). The results showed that the 225 mg L^{-1} glutathione had significant positive efficacy on plant height, branches per plant, leaf area, pod numbers, seed number per pod, weight of 100 seeds, individual plant yield, glutathione content in leaves, SOD enzyme activity, vascular bundle thickness, and density of starchy matter stored in the pith (83.22 cm, 7.00 plant $shoot^{-1}$, 23.77 dm^2, 74.22 plants pod^{-1}, 2.644 seed pod^{-1}, 13.733 g, 31.9 g $plant^{-1}$, 11.371 micromole g^{-1} fresh weight, 10.211 g^{-1} fresh weight). Also, while the Giza 82 variety was superior in leaf area and fertility percentage (23.07 cm^2, 94.44%), the Giza 35 variety excelled in pod numbers, individual plant yields, glutathione percentage in the leaves, and SOD enzyme activity.

Keywords: Anatomy, Enzyme activity, Glutathione, Soybeans.

التغايرات في نمو وحاصل وتشريح لثلاث أصناف من فول الصويا (Glycine max L. – Fabaceae) بتأثير الرش بالجلوتاثيون

ياسين عبد الجنابي[1] أحمد جياد الفهد[1] معزز عزيز الحديثي[2]*
فانوم سوشسكابون[3] هديل خليل رحمن[2]
[1] قسم المحاصيل الحقلية، كلية الزراعة، جامعة الانبار
[2] قسم علوم الحياة، كلية التربية للعلوم الصرفة ابن الهيثم، جامعة بغداد
[3] كلية البيئة للزراعة والسياحة، جامعة سرنكارينروت، بانكوك، تايلاند

***المراسلة الى:** معزز عزيز حسن الحديثي، قسم علوم الحياة، كلية التربية للعلوم الصرفة ابن الهيثم، جامعة بغداد، العراق.
البريد الالكتروني: muazaz.a.h@ihcoedu.uobaghdad.edu.iq

الخلاصة

أجريت الدراسة في حقول مدينة أبو غريب في بغداد خلال صيف 2022 وفق تصميم الألواح المنشقة RCBD وبثلاث مكررات. تضمنت الدراسة عاملين، يمثل العامل الأول تراكيز الجلوتاثيون (0، 75، 150، 225) ملغم لتر$^{-1}$، أما العامل الثاني فيشمل ثلاثة أصناف من فول الصويا (الجيزة 82 والجيزة 83 والجيزة 35). أظهرت النتائج أن لتركيز 225 ملغم لتر$^{-1}$ جلوتاثيون فعالية إيجابية كبيرة على الخصائص التالية، ارتفاع للنبات، عدد الأفرع في النبات، المساحة الورقية، عدد القرنات، عدد البذور في القرنة، وزن 100 بذرة، حاصل النبات الفردي، نسبة الجلوتاثيون في الأوراق، نشاط إنزيم SOD، سمك الحزمة الوعائية وكثافة المادة النشوية المخزونة في اللب (83.22 سم، 7.00 شتلة نبات$^{-1}$، 23.77 دسم^{2}، 74.22 نبات–قرنة$^{-1}$، 2.644 بذرة قرنة$^{-1}$، 13.733 غم، 31.9 جم نبات$^{-1}$، 11.371 ميكرومول غم$^{-1}$ وزن طازج، 10.211 غم$^{-1}$ وزن طازج). على جانب آخر فان الصنف جيزة 82 قد تفوق في المساحة الورقية ونسبة الخصوبة (23.07 سم2، 94.44%). وفي المقابل ان الصنف جيزة 35 كان جيدا في عدد القرنات، وإنتاجية النبات الفردي، ونسبة الجلوتاثيون في الأوراق، ونشاط إنزيم SOD.

كلمات مفتاحية: التشريح، نشاط الانزيم الجلوتاثيون، فول الصويا.

Introduction

Soybean is one of the main leguminous crops due to its nutritional properties comprising between 30-50% protein, oil (14-24%), in addition to amino acids, vitamins, and fatty acids (13). Much interest has been shown by researchers in increasing soybean yields and narrowing the gap between production and consumption by increasing production per unit area in view of the many problems afflicting the crop, especially in Iraq where farmers are generally unwilling to grow this crop (9). The summer crop faces by many obstacles, including the impact of environmental conditions on growth and production, causing the flowers to fall at the end of the season, which harms the yield (10). Most leguminous crops have this problem, and there is a need to reduce losses and increase production using varieties adapted to local conditions that offer better yields to encourage farmers to expand the cultivation of this crop and improve its productivity.

To increase production and reduce pollution from using fertilizers, it is important to apply materials that increase yields without harming the environment. One method is the use of glutathione, a tripeptide consisting of three amino acids (glutamic, steine, and glycine), which helps balance oxidation and antioxidants and regulates many cell activities and enzymes (12 and 21). It also has an important role in metabolic processes and cell division, in addition to its resistance to strong metals and pesticides, and in the flowering of various plants (20). Despite glutathione's role in increasing agricultural production by improving growth characteristics and yield (7 and 8) there is a lack of studies in this aspect in Iraq. As such, this study identified the most important varieties that respond to glutathione and determine the best concentration for achieving the highest yield in cultivated soybean varieties.

Materials and Methods

This field experiment was conducted in the summer season of 2022 in the pastures of a farmer in Iraq's Abu Ghraib region (longitude 44.21 degrees east and latitude 33.31 degrees north). Based on a randomized complete block design (RCBD) in a split-plot arrangement with three replications the study sought to evaluate the physiological and anatomical behavior of three soybeans varieties. The soyabeans were split into 36 experimental units, with three replicates each of 12 experimental units, and planted 2 meters apart. The experimental unit contained four sub plots of 3 m lengths, with a 75 cm distance between each sub plot giving a total experimental unit area of 9 m2. Two factors were involved in this study. The first one involved spraying three concentrations of glutathione (0, 75, 150, and 225 mg L^{-1}) on the plants with one spray after four weeks of germination (at the stage of forming eight leaves) in the early morning using a 15 liter backpack sprayer.

A 2-gm. concentration water dispersing material (Al-Zahi) was dissolved in 15 liters of water to raise absorption and minimize the surface density of water until complete wetness (5). The second factor included three varieties of soybeans (Giza 82, Giza 83, and Giza 35) planted on 6/1/2022 in the upper third of the farm to avoid suffocation of the seeds. Three seeds each were planted in 3-cm deep holes spaced 25 cm apart. Phosphate fertilizer (46% P2O) was added to the soil at a rate of 100 kg H^{-1} before planting, and mixed with the soil in one batch before planting. Nitrogen fertilizer was inserted as urea at a level of 60 kg N H^{-1} in two batches, the first at sowing, and the second at the bloom stage for all units (6).

The anatomical study was carried out at the College of Education for Pure Sciences Ibn-AL-Haitham/University of Baghdad, in 2022. In the vegetative stage, the stems were cut from the center to prepare samples for sectioning as (18) with some modifications according to (17) The stems were cut into thin pieces of 4-6 cm. length with a razor blade and treated with 0.5% sodium hypochlorite for 10 min to remove the chlorophyll pigments. Finally, the samples were placed mounted on slides by D.P.X.

and fixed by a KRÜSS light microscope, then photographed using Am scope camera Model MU 1000.

The following characteristics were studied: plant height, branch numbers, leaf area, pod numbers, fertility rate, seeds per pod, weight of 100 seeds, individual plant yield, glutathione content in leaves, superoxide dismutase (SOD) enzyme activity, and anatomical differences in vascular bundles stem thickness.

SOD enzyme activity was calculated after extracting the highest percentage of inhibition from the standard inhibition curve and its effectiveness based on the following equation:

$$\text{SOD (inhabitation\%)} = \frac{(\mathrm{A2S}-\mathrm{A1S})-(\mathrm{A2B}-\mathrm{A1B})}{(A2B-A1B)} * 100$$

where,

A1B = blank absorbance value before illumination

A2B = blank absorbance value after illumination

A1S = absorbance value of the sample before illumination

A2S= absorbance value of the sample after illumination

One unit of SOD is defined as the sample quantity VS which decreases nitro blue tetrazolium (NBT) by 50%. Therefore, SOD value can be expressed as follows:

SOD effectiveness (unit ml^{-1}) = (sample inhibition %)/(sample inhibition %)) × D.F / VS(Ml)

D.F. Dilution factor (2000 µl)

U: Unit

Vs: sample volume (40 µl)

Data were analyzed statistically at $P<0.05$ using Genstat software. Least significant differences at 5% level of probability (LSD 5%) was used to compare the calculated averages of the traits (Steel and Torrie, 1980).

Results and Discussion

Plant height (cm): As shown in Table 1, spraying glutathione on the vegetative part of the plant had a significant effect on increasing the plant height when treated with a 225 mg L^{-1} which gave a high average ranking of 83.22 cm compared to 82.95 cm for 150 mg L^{-1}. The comparison treatment recorded the lowest average plant height of 79.56 cm. The difference might be due to the high concentration of glutathione, because it reflects on cell division, elongation, and differentiation until the end of the plant's life cycle. This result is consistent with (24), who indicated that spraying plants with glutathione led to an increase in plant height. The interaction between the study factors also recorded a significant effect on the average of the Giza 82 varieties sprayed with a 255 mg L^{-1} glutathione concentration with plant height reaching 90.33 cm, the Giza 35 variety without spraying had the lowest average plant height at 74.33 cm.

Table 1: Impact of glutathione concentrations on plant height of soybean varieties (cm).

Glutathione spray concentration (mg L^{-1})	Cultivars			Average
	Giza 82	Giza 83	Giza 35	
0	77.33	87.00	74.33	79.56
75	76.85	83.00	82.00	80.62
150	78.18	81.33	89.33	82.95
225	90.33	77.33	82.00	83.22
LSD 5%		4.488		2.184
Average	80.68	82.17	81.92	
LSD 5%		N.S.		

Number of branches per plant or branches $plant^{-1}$: Table 2 indicates that plants sprayed 225 mg L^{-1} glutathione concentration were had the highest average for this trait, reaching 7.002 branches per $plant^{-1}$, while the comparison treatment gave the lowest number at 6.463 branches per $plant^{-1}$. The increase in the number of branches when sprayed with glutathione is due to its role in increasing the activity of enzymes and hormones, as it works to remove toxins from reactive oxygen species (ROS) through antioxidant enzymes, namely glutathione reductase (GR), glutathione peroxidase (GPX), and glutathione transferase (GST) (19), which may affect the longitudinal and transverse cell division and thus reflect on branch numbers. There was also significant interaction between the varieties and concentricity of glutathione spraying, as Giza variety sprayed at 225 mg $plant^{-1}$ had 7,590 branches $plant^{-1}$, while Giza 82 without spraying recorded 5,740 plant branches1.

Table 2: Impact of glutathione concentrations on number of branches per plant of soybean varieties (per $plant^{-1}$).

Glutathione spray concentration (mg L^{-1})	Cultivars			Average
	Giza 82	Giza 83	Giza 35	
0	5.740	6.497	6.923	6.386
75	7.313	5.790	6.530	6.544
150	6.663	7.527	5.970	6.720
225	6.530	6.887	7.590	7.002
LSD 5%		0.5040		0.1732
Average	6.561	6.675	6.696	
LSD 5%		N.S.		

Leaf area (dm^2): Table 3 shows important dissimilarity among the varieties planted and sprayed with glutathione, and the interaction among them in the average leaf area trait. The plants of the Giza 82 excelled by recording the highest leaf area of 23.07 dm^2, while the Giza 83 have the lowest average at 22.02 dm^2. This could be due to differences in the genetic composition of the cultivated varieties, and is in line with (3) who had similar findings. Also, plants sprayed with glutathione at 225 mg L^{-1} recorded a high level of leaf area, at 23.77 dm^2, while the comparison treatment recorded only 20.92 dm^2. The glutathione activity of many enzymes and hormones help in cell division and thus growing the leaf area, as well as its role in protecting cells and their structure from oxidative damage. This finding is in line with (11) who noted the significant differences from spraying glutathione on the foliage of plant leaves. Also there was notable reaction on the mean of this trait, as plants of the Giza 82 sprayed

75% glutathione recorded the highest mean at 26.31 dm^2, compared to plants of the same variety that were not sprayed which recorded a low mean of 20.07 dm^2.

Table 3: Impact of glutathione concentrations on leaf area of soybean varieties (dm^2).

Glutathione spray concentration (mg L^{-1})	Cultivars			Average
	Giza 82	Giza 83	Giza 35	
0	20.07	22.53	20.16	220.9
75	26.31	20.16	22.59	23.02
150	22.86	22.75	23.26	22.96
225	23.03	22.65	25.63	23.77
LSD 5%		0.5040		0.839
Average	23.07	22.02	22.91	
LSD 5%		0.594		

Number of pods per plant (pods $plant^{-1}$): Table 4 shows the differences among cultivated soybeans in the mean of this trait. The Giza 35 plants had the highest average pod numbers at 71.40 per plant compared to the lowest at 68.34 for the Giza 82. The good performance of the former may be due to its genetic capacity to change the outcome of the carbon assimilation process into newly formed flowers and pods. This agrees with (23) that soybean cultivars vary in pod number. Also, spraying the soybean with glutathione at 225 mg L^{-1} led to significant growth in the pod's number 74.22 pods $plant^{-1}$, while the comparison treatment had the lowest at 63.61 pods $plant^{-1}$. This higher figure is due to its role in increasing plant height, branches number and leaves (Tables 1, 2, and 3), which contribute significantly in increasing the processed food and its transfer to new centers of growth, thus increasing the percentage of nodes, and are consistent with the findings of (11). The binary interaction also had a noticeable effect on the mean with the Giza 83 sprayed with 150 mg L^{-1} per plant of glutathione registering a high mean of 81.15 pods $plant^{-1}$.

Table 4: Interaction of varieties and glutathione concentrations on the number of pods per plant of the studied soybean.

Glutathione spray concentration (mg L^{-1})	Cultivars			Average
	Giza 82	Giza 83	Giza 35	
0	51.58	65.74	73.52	63.61
75	78.95	54.32	69.96	67.74
150	75.78	81.15	62.04	72.99
225	67.04	75.53	80.08	74.22
LSD 5%		3.271		1.998
Average	68.34	69.19	71.40	
LSD 5%		1.751		

Fertility rate: Table 5 shows the significant variations among studied varieties and factors with Giza 82 recording the highest mean for this feature at 94.44%, while Giza 35 had a low mean of 91.42%. This could be attributed to the Giza 82 plants maintaining pollen viability for a longer period than the other varieties due to their different genetic compositions, which increases the fertility rate. These results are consistent with (9) who noted that the varieties differ in the percentage of pod growth. There was also significant interactions in the study factors for Giza 82 sprayed at 150 mgL^{-1} which recorded a high fertility rate of 94.81% compared with 90.40% for the unsprayed Giza 35 variety.

Table 5: Impact of varieties and glutathione concentrations on the soybean fertility rates.

Glutathione spray concentration (mg L^{-1})	Cultivars			Average
	Giza 82	Giza 83	Giza 35	
0	94.14	92.79	90.40	92.44
75	94.47	90.37	91.96	92.26
150	94.81	92.08	91.00	92.63
225	94.33	94.41	92.33	93.69
LSD 5%	1.446			1.998
Average	94.44	92.41	91.42	
LSD 5%	0.703			

Seed number per pod (seed pod^{-1}): As seen in Table 6 there were significant differences in the binary interaction between glutathione spray concentrations and seed number per pod. The plants treated with 225 mg L^{-1} was the best yielding a mean of 2.644 seed pod^{-1} while the control treatment had a low mean of 2.267 seeds per pod. These variations may be due to glutathione's role in regulating the transfer of nutrients at the beginning of pod formation and increasing the activity of hormones responsible for flower and seed formation. The interaction among varieties and the concentration of glutathione also affected the number of seeds per pod. Giza 35 sprayed with 225 mg L^{-1} of glutathione achieved a high mean of 2.833 seeds per pod, while Giza 82 without spraying had a low mean of 2.100 seeds pod^{-1}.

Table 6: Impact of the glutathione concentrations on the number of seeds per pod of soybean varieties.

Glutathione spray concentration (mg L^{-1})	Cultivars			Average
	Giza 82	Giza 83	Giza 35	
0	2.100	2.267	2.433	2.267
75	2.667	2.200	2.367	2.411
150	2.500	2.767	2.267	2.511
225	2.467	2.633	2.833	2.644
LSD 5%		0.1167		0.0577
Average	2.433	2.467	2.475	
LSD 5%		N.S.		

Weight of 100 seeds: Table 7 shows that spraying the soybean with 225 mg L^{-1} of glutathione produced the highest mean weight of 100 seeds at 13.733 grams, while the control treatment without spraying registered only 12.142 grams. This difference in weights is related to growth factors such as the higher leaf area (Table 3) which improve photosynthesis, leading to greater efficiency of the source in forming nutrients and the ability of the downstream in absorbing these elements, thus increasing the rate of grain filling. These results agree with (1 and 4). They also confirm that binary interactions had a significant effect on the weight of 100 seeds, as Giza 83 sprayed with 150 mg L^{-1} glutathione gave a high mean of 14.950 grams, while the unsprayed Giza 82 had a low mean of 11.333 grams.

Table 7: Impact of glutathione concentrations on 100 gr. of seed weight (grams) in the soybean varieties.

Glutathione spray concentration (mg L^{-1})	Cultivars			Average
	Giza 82	Giza 83	Giza 35	
0	11.333	12.333	12.760	12.142
75	14.233	12.167	12.893	13.098
150	13.450	14.950	11.967	13.456
225	12.667	13.723	14.810	13.733
LSD 5%		0.6746		0.4433
Average	12.921	13.293	13.107	
LSD 5%		N.S.		

Individual plant yield: Table 8 shows the significant differences among the varieties sprayed with glutathione and the interaction among them in terms of individual plant yield. Giza 35 had the highest mean at 27.2 gm. plant^{-1} compared with the 22.2 gm. plant^{-1} for Giza 82. The higher yield was due to the excess number of pods for Giza 35 (Table 4), as well as variations in the genetic composition of varieties. These results agree with (2 and 25). The concentration of 225 mg L^{-1} achieved the highest mean of 31.9 gm plant^{-1}, while the comparison treatment had the lowest at 17.9 gm plant^{-1}. The results also show a high yield of 47.5 gm plant^{-1} for Giza 35 when sprayed with glutathione, while the unsprayed Giza 82 registered the lowest at 12.3 gm plant^{-1}.

Table 8: Impact of glutathione concentrations on individual plant yields (grams) in the soybean varieties.

Glutathione spray concentration (mg L^{-1})	Cultivars			Average
	Giza 82	Giza 83	Giza 35	
0	12.3	18.4	22.9	17.9
75	30.1	14.5	21.3	22.0
150	25.5	33.8	16.9	25.4
225	21.0	27.2	47.5	31.9
LSD 5%		6.62		8.40
Average	22.2	23.5	27.2	
LSD 5%		3.52		

Percentage of glutathione in leaves (micromole g^{-1} fresh weight): The percentage of glutathione in the leaves as shown in Table 9 differed according its concentrations and the binary interaction of the study factors. Plants sprayed with 225 mg L^{-1} concentrations significantly outperformed others with a mean of 11.371 micromole g^{-1} fresh weight compared to the mean of 8.594 for the unsprayed variety. The variations in glutathione level in leaves due to spraying with different glutathione concentrations increased glutathione reductase activity and thus the GSH/GSSH ratio, which in turn prevents the state of natural oxidation that reduces the rate of cell damages. These results agree with (25). Spraying Giza 35 with 225 mg L^{-1} provided a high percentage of 13.143 micromole g^{-1} fresh weights, while Giza 82 registered a low mean of 6.630.

Table 9: Interaction between concentrations of glutathione sprays on the percentage of glutathione in leaves (micromole g^{-1} fresh weight) in the soybean varieties.

Glutathione spray concentration (mg L^{-1})	Cultivars			Average
	Giza 82	Giza 83	Giza 35	
0	6.630	8.110	11.043	8.594
75	12.040	6.933	9.010	9.328
150	11.833	12.917	7.443	10.731
225	9.160	11.810	13.143	11.371
LSD 5%		0.8732		0.8003
Average	9.916	9.942	10.160	
LSD 5%		N.S		

Superoxide dismutase enzyme activity: Table 10 shows the significant variations among the varieties and concentrations of glutathione sprays and the interaction among them in the vigor of the SOD enzyme (superoxidase dismutase). The effectiveness of SOD increased in the Giza 35 variety, registering a high mean of 9.943 absorption units gm^{-1} fresh weight, while that for Giza 82 only had a mean of 9.664. The results in the same table also showed that the plants sprayed with glutathione at a high concentration of 225 mg L^{-1} recorded a significant increase in the activity of SOD enzyme, reaching 10.21 absorption units g^{-1} fresh weight, while the comparison treatment recorded the lowest average for this trait, reaching 9.20 absorption units g^{-1} fresh weight. This may be due to the role of glutathione in increasing antioxidant activity and its contribution to protein synthesis, which leads to improving the effectiveness of enzymes, including the SOD enzyme, in protecting cells from free radical damage and limiting the oxidation process. These results agree with what (22).

Table 10: Glutathione concentrations and their interactions on the rate of SOD enzyme activity in the soybean varieties.

Glutathione spray concentration (mg L^{-1})	Cultivars			Average
	Giza 82	Giza 83	Giza 35	
0	8.500	9.150	9.963	9.204
75	10.483	8.730	9.560	9.591
150	9.373	10.273	10.863	10.170
225	10.300	10.950	9.383	10.211
LSD 5%		0.3904		0.1625
Average	9.664	9.776	9.943	
LSD 5%		0.2271		

Anatomical study: In terms of anatomy (Table 1), Figures 1 - 6 show that cross-sections of the stems in the studied soybean had quadrilateral shapes and polygonal angles. They were composed of a thin layer of cuticle, followed by the epidermis layer, composed of a single layer of oval-shaped cells, followed by the cortex, and then the vascular cylinder. In both varieties, the vascular bundle is continuous, being in the stage of secondary growth between early and complete. The xylem vessels during the secondary xylem are not of equal diameter, which is known as the ring-pours wood type. In the center of the stem lies the pith, which is composed of parenchymal cells (Figure 1A).

The study revealed the presence of variations in the growth of the vascular bundle and density of the starchy substance stored in the pith region during the different glutathione treatments and also among the different cultivated soybeans. The stems of plants sprinkled with 225 mg L^{-1} glutathione concentration in all the cultivated soybeans (Giza 82, Giza 83, and Giza 35) were in an early secondary growth stage and can be distinguished from the other bundles. The vascular bundle reached 315, 299, and 318 µm, respectively (Figures 1B, 2B, and 3B) compared to the control treatment at 309, 279, and 301 µm. The plants treated with glutathione concentration of 75 mg L^{-1} were 188, 301, and 272 µm respectively while that with 150 mg L^{-1} concentrations had 242, 295, and 282 µm where the vascular bundles had complete growth and could not be distinguished (Figure 1, 2, 3 C, D and Diagram 1) (14).

There was also an increase in the starch stored in the stem pith in plants treated with 225 mg L^{-1} glutathione concentration (Figures 4B, 5B, and 6B) and a decrease for other concentrations in all the cultivated soybean (Figure 4, 5, 6 A, C, and D). The 225 mg L^{-1} concentration had the best results keeping the vascular bundle in an active stage for the transport process and delivering the absorbed materials and nutrients to the rest of the plant. This is clear from the amount of starch present in the stem pith, which was accompanied by a broader leaf area (Table 3), thus enhancing the process of food synthesis in the leaf and storing the excess in various plant tissues, including the parenchyma cells in the stem pith (16). In contrast to other concentrations, this level accelerated secondary growth of the stem, where xylem vessels form in the aging stage and new vessel formation decreases during the process of transporting nutrients to the rest of the plant. This is reflected in the amount of starch stored in the pith of the stem (15).

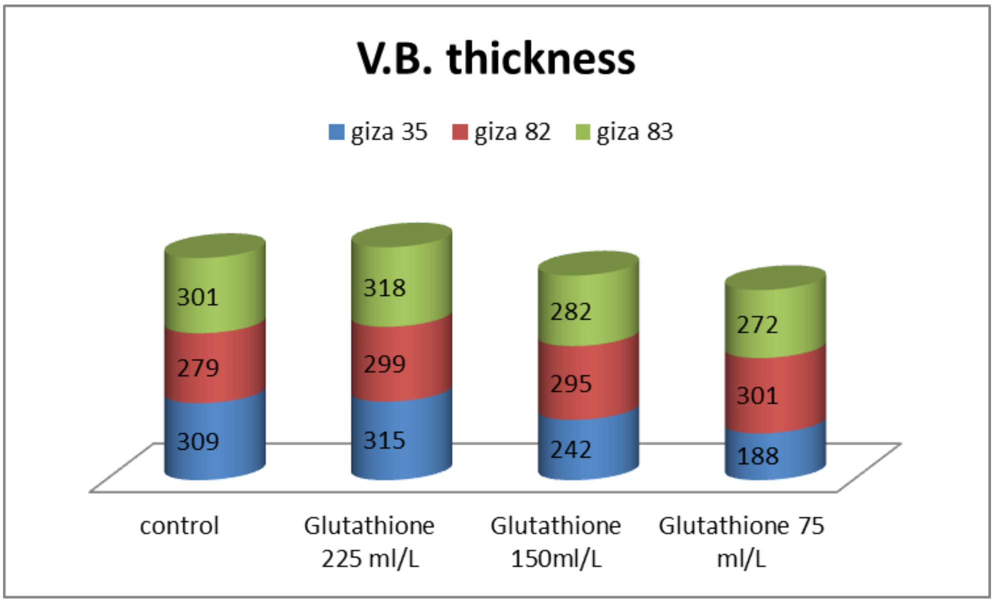

Diagram 1: Vascular bundle thickness in the soybean varieties.

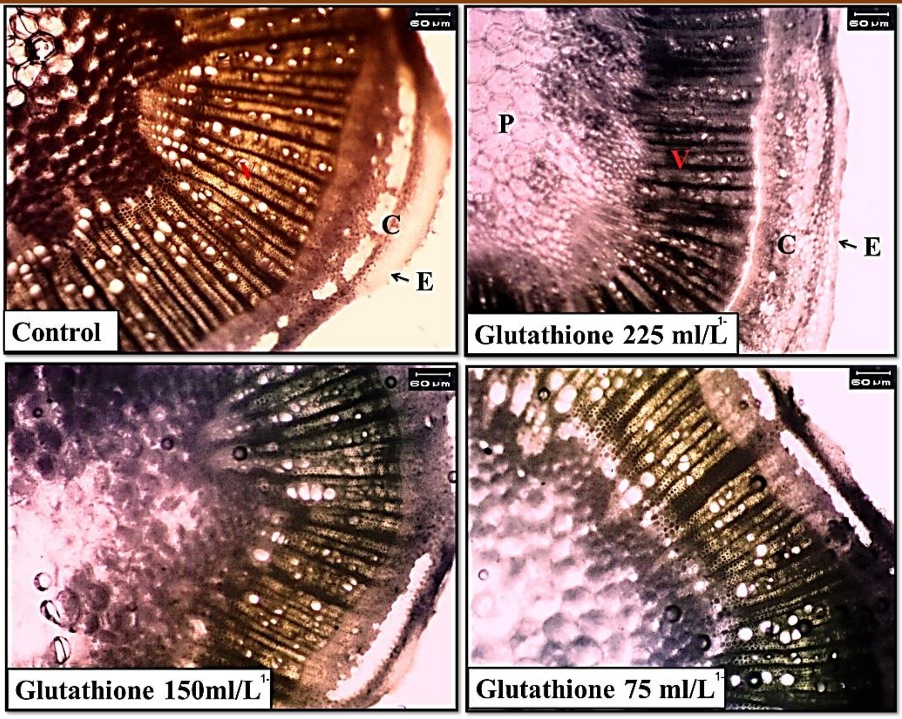

Figure 1: Stem cross sections of the Giza 35 soybean. A: control treatment; B: 225 mg L^{-1}; C: 125 mg L^{-1}; D: 75 mg L^{-1}; E: epidermis; C: cortex; V: vascular bundle; P: pith.

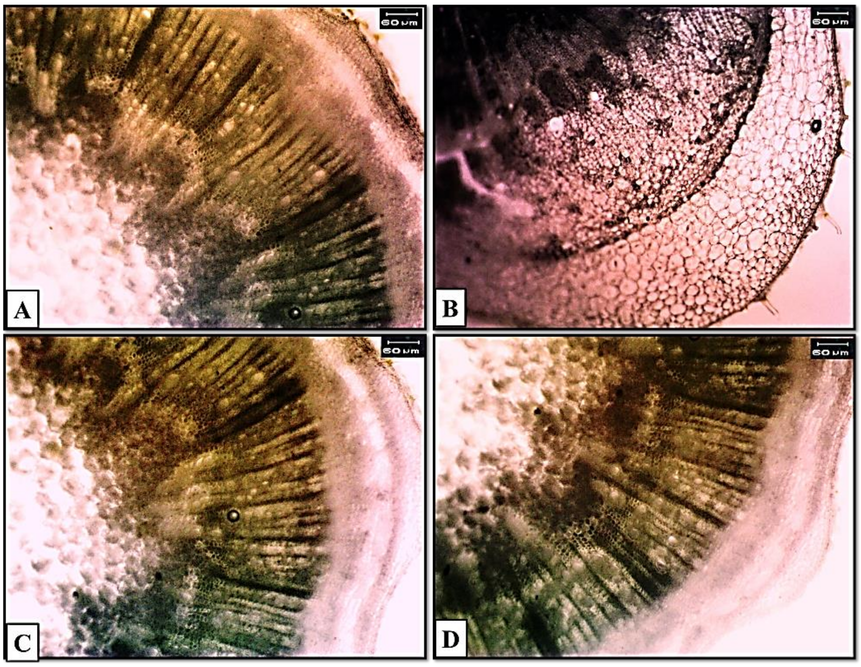

Figure 2: Stem cross sections of the Giza 82 soybean. A: control treatment; B: 225 mg L^{-1}; C: 125 mg L^{-1}; D: 75 mg L^{-1}.

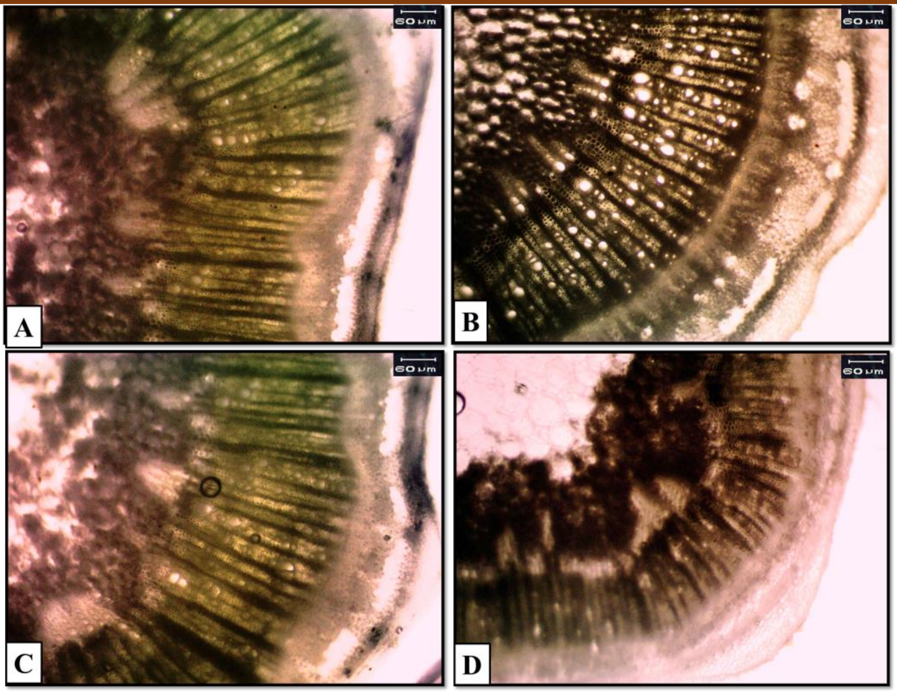

Figure 3: Stem cross sections of the Giza 82 soybean. A: control treatment; B: 225 mg L^{-1}; C: 125 mg L^{-1}; D: 75 mg L^{-1}.

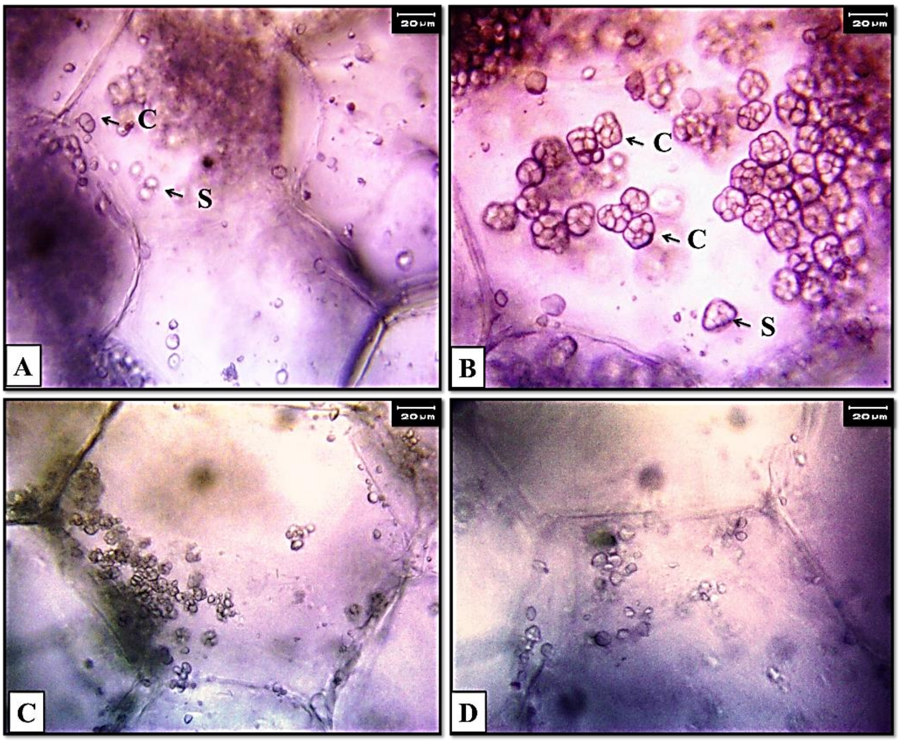

Figure 4: Magnified portion of the pith of the Giza 35 stem. A: control; B: 225 mg L^{-1}; C: 125 mg L^{-1}; D: 75 mg L^{-1}; S: simple starch grains; C: complex starch grains.

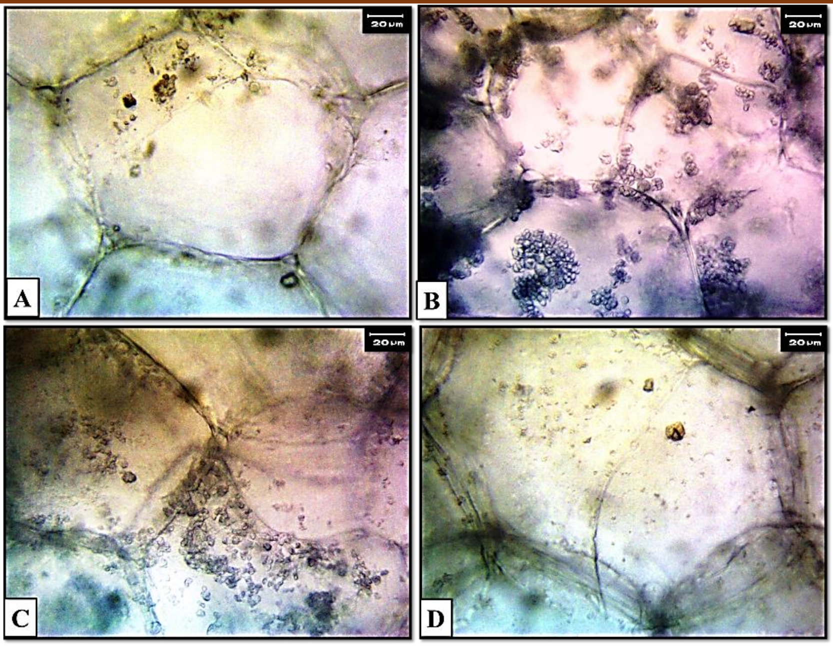

Figure 5: Magnified portion of the pith of the Giza 82 stem. A: control; B: 225 mg L^{-1}; C: 125 mg L^{-1}; D: 75 mg L^{-1}.

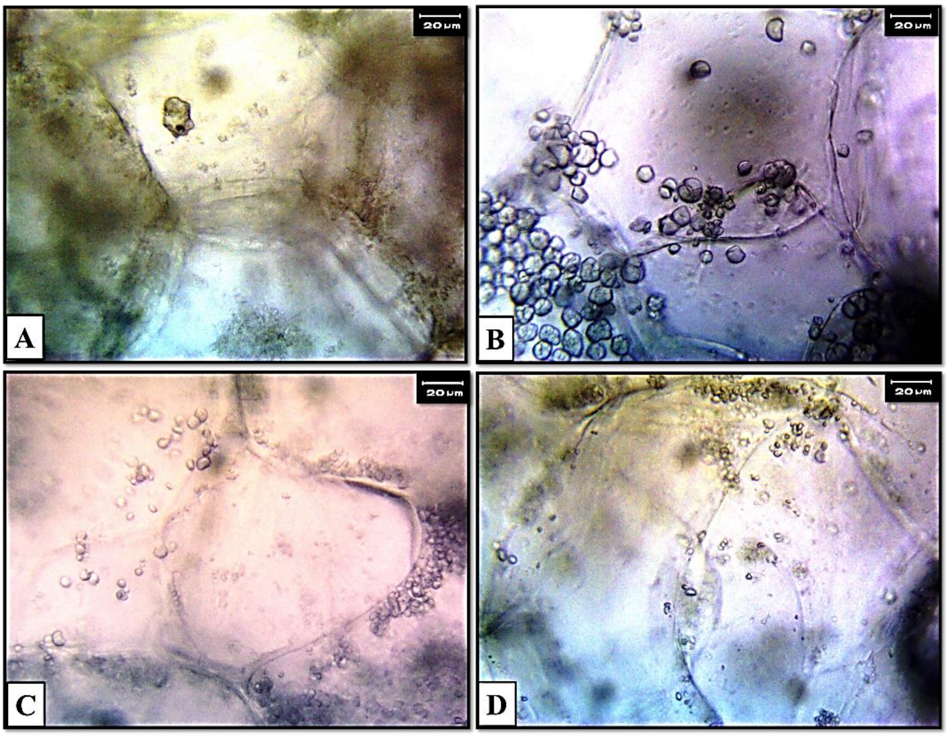

Figure 6: Magnified portion of the pith of the Giza 35 stem. A: control; B: 225 mg L^{-1}; C: 125 mg L^{-1}; D: 75 mg L^{-1}.

Conclusions

Although the varieties did not differ in most growth characteristics, they produced different plant yields. The Giza 35 excelled with an average 27.2 gm plant^{-1}, as well as in the characteristics of glutathione ratio in the leaves and effectiveness of the SOD enzyme (10.16 micromole g^{-1} fresh weight and 9.94 SOD). Moreover, a high glutathione concentration led to significant benefits in terms of growth, anatomical characteristics, and yield.

Supplementary Materials:

No Supplementary Materials.

Author Contributions:

All authors: methodology; Authors 1 and 2: writing original draft; Authors 3 and 4: review and editing. All authors have read and agreed to the published version of the manuscript.

Funding:

This research received no external funding.

Institutional Review Board Statement:

The study was conducted in accordance with the protocol authorized by the Ministry of Higher Education and Scientific Research, Iraq.

Informed Consent Statement:

No Informed Consent Statement.

Data Availability Statement:

No Data Availability Statement.

Conflicts of Interest:

The authors declare no conflict of interest.

Acknowledgments:

The authors thank the College Dean, and Head of the Field Crops Dept., College of Agriculture, University of Anbar, Iraq for their valuable help and technical assistance in conducting this research.

References

1. Abd Elhamid, E. M., Sadak, M. S., and Tawfik, M. M. (2018). Glutathione treatment alleviate salinity adverse effects on growth, some biochemical aspects, yield quantity and nutritional value of chickpea plant. Sci Fed J Global Warming, 2(2): 1-11.
2. Abdel-Baky, Y. R., Abouziena, H. F., Amin, A. A., Rashad El-Sh, M., and Abd El-Sttar, A. M. (2019). Improve quality and productivity of some faba bean cultivars with foliar application of fulvic acid. Bulletin of the National Research Centre, 43: 1-11. https://doi.org/10.1186/s42269-018-0040-3.
3. Abid, G., Hessini, K., Aouida, M., Aroua, I., Baudoin, J. P., Muhovski, Y., ... and Jebara, M. (2017). Agro-physiological and biochemical responses of faba bean (Vicia faba L. var.'minor') genotypes to water deficit stress. Biotechnologie, Agronomie, Société et Environnement, 21(2). http://dx.doi.org/10.25518/1780-4507.13579.

4. Abo Zahra, E. S. (2020). Impact of foliar and soil fertilization on productivity and quality of some soybean cultivars under calcareous soil conditions. Zagazig Journal of Agricultural Research, 47(4): 867-881. https://doi.org/10.21608/zjar.2020.110314.
5. Abu Dahi, Y. M., Lahmoud, A. M., and Al-Kawaz, G. M. (2001). Effect of foliar nutrition on maize yield and its components. Iraqi Journal of Soil Sciences. 1(1): 69-81.
6. Al-jughaify, S. F., A., & Sh. J. Alobaidy, B. (2024). Response To Some Tolerance Standards Of Salinity Stress To Adapt The Seeds Of Wheat Varieties With Salty Water And Growth Regulators. Anbar Journal Of Agricultural Sciences, 22(1), 331–342. https://doi.org/10.32649/ajas.2024.183733.
7. Ali, N. S. (2012). Fertilizers and their Applications. Ministry of Higher Education and Scientific Research, University of Baghdad - College of Agriculture. 220 P.
8. Al-Issawi, A. K. M., and Al-Fahad, A. C. (2023). Response of Sorghum Seeds to Soaking with Antioxidants (Glutathione) and Grown at Three Temperatures in Laboratory Conditions. In IOP Conference Series: Earth and Environmental Science, 1259(1): p. 012096. DOI: 10.1088/1755-1315/1259/1/012096.
9. Al-Issawi, A. M., and Al-Fahad, A. C. (2023). Effect of Foliar Apllication of Glutathione on Viability and Vigor Seeds of Sorghum Effected by Heat Stress. In IOP Conference Series: Earth and Environmental Science, 1252(1): p 012026. DOI: 10.1088/1755-1315/1252/1/012026.
10. Al-Jobouri, S. M. I., and AL-Dawdi, A. H. R. (2017). Physiological changes in Growth Parameters Under Main Effects of Bio Fertilizer EM1 and Phosphorus Fertilizer of Two Soybean Varieties [Glycine max (L.) Merrill]. Kirkuk University Journal for Agricultural Sciences (KUJAS), 8(1): 42-55. DOI: 10.58928/ku17.08106.
11. Alotaibi, M. (2023). Climate change, its impact on crop production, challenges, and possible solutions. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 51(1): 13020-13020. https://doi.org/10.15835/nbha51113020.
12. Al-Saadi, S. F. M. (2021). The effect of spraying with glutathione and nano-zinc oxide and their interaction on the growth and yield of faba beans (*Vicia faba* L.) exposed to salt stress, PhD. thesis, College of Education for Pure Sciences, Ibn al-Haytham, University of Baghdad, p. 199.
13. Balavandy, S. K., Shameli, K., Biak, D. R. B. A., and Abidin, Z. Z. (2014). Stirring time effect of silver nanoparticles prepared in glutathione mediated by green method. Chemistry Central Journal, 8, 1-10. https://doi.org/10.1186/1752-153X-8-11.
14. Bilyeu, K., Ratnaparkhe, M. B., and Kole, C. (Eds.). (2016). Genetics, genomics, and breeding of soybean. CRC Press. https://doi.org/10.1201/EBK1578086818.
15. Gomaa, E. F., Nassar, R. M., and Madkour, M. A. (2015). Effect of foliar spray with salicylic acid on vegetative growth, stem and leaf anatomy, photosynthetic pigments and productivity of Egyptian lupine plant (Lupinus termis Forssk.). International Journal of Advanced Research, 3(1) 803-813.
16. Hasan, M. A., Al-Taweel, S. K., Alamrani, H. A., Al-Naqeeb, M. A., Al-Baldawwi, M. H. K., and Hamza, J. H. (2018). Anatomical and physiological traits

of broad bean (Vicia faba L.) seedling affected by salicylic acid and salt stress. Indian Journal of Agricultural Research, 52(4): 368-373. http://dx.doi.org/10.18805/IJARe.A-343.

17. Hasan, M. A., Al-Taweel, S. K., Hamza, J. H., and Jewad, W. M. (2018). Effect of seed weight on stem anatomical characters in white lupine (Lupinus¡ albus L.) cultivars. Indian Journal of Agricultural Research, 52(6): 666-670. http://dx.doi.org/10.18805/IJARe.%20A-352.
18. Hutchinson, E. P. (1954). Sectioning methods for moss leaves. The Bryologist, 57(2): 175-176.
19. Kareem, T., R., & T. F. Alkhamisi, F. (2024). Flowering Time Gene Expression of Gmtf2a And Some Pod And Seed Characteristics Of Soybean Affected By Spraying With Melatonin And Seeding Date. Anbar Journal Of Agricultural Sciences, 22(1), 415–428. https://doi.org/10.32649/ajas.2024.183743.
20. Noctor, G., Queval, G., Mhamdi, A., Chaouch, S., and Foyer, C. H. (2011). Glutathione. The Arabidopsis Book/American Society of Plant Biologists, :1-32. https://doi.org/10.1199/tab.0142.
21. Pompella, A., Visvikis, A., Paolicchi, A., De Tata, V., and Casini, A. F. (2003). The changing faces of glutathione, a cellular protagonist. Biochemical pharmacology, 66(8): 1499-1503. https://doi.org/10.1016/S0006-2952(03)00504-5.
22. Sadak, M., Abd Elhamid, E., and Mahmoud, M. (2017). Glutathione induced antioxidant protection against salinity stress in chickpea (Cicer arietinum L.) plant. Egyptian Journal of Botany, 57(2): 293-302. https://dx.doi.org/10.21608/ejbo.2017.636.1029.
23. Tambunan, S., Afkar, A., and Sebayang, N. S. (2019). Growth and yields response of some varieties of soybean (Glycine max (L) merill) on ultisol soil. Indonesian Journal of Agricultural Research, 2(3): 196-204. http://dx.doi.org/10.32734/injar.v2i3.2035.
24. Ur Rehman, H., Alharby, H. F., Bamagoos, A. A., Abdelhamid, M. T., and Rady, M. M. (2021). Sequenced application of glutathione as an antioxidant with an organic biostimulant improves physiological and metabolic adaptation to salinity in wheat. Plant Physiology and Biochemistry, 158: 43-52. https://doi.org/10.1016/j.plaphy.2020.11.041.
25. Zaki, S. S., and Mohamed, G. F. (2018). Alleviating effects of ascorbic acid and glutathione for faba bean plants irrigated with saline water. Journal of Plant Sciences, 2(2): 80-94.