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EFFECT OF ETHEPHON SPRAYING ON SEEDS YIELD AND ITS COMPONENTS OF DIFFERENT SOYBEAN CULTIVARS

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ABSTRACT

A field experiment was conducted at the fields of the College of Agricultural Engineering Sciences, University of Baghdad, during the summer season of 2023 to study the effects of ethephon foliar application on the growth, yield, and quality of indeterminate soybean cultivars. The experiment was carried out using a randomized complete block design (R.C.B.D) with a split-plot arrangement using three replicates. This study included three soybean cultivars (Shaimaa, Giza 22 and Giza 111) and four foliar treatments (100, 200, and 300 mg L^{-1} of ethephon, along with a distilled water control). The results revealed that the Giza 22 cultivar achieved the highest means of number of pods per plant (96.16 pods plant^{-1}) and total seeds yield (2.51 Mg ha^{-1}). The Shaimaa cultivar recorded the highest means of 100 seeds weight (15.88 g) and protein content (38.14%). Foliar application with concentration of 300 mg L^{-1} significantly enhanced the number of pods per plant (104.90 pods plant^{-1}), seeds per pod (2.93 seeds pod^{-1}) and total seeds yield (2.59 Mg ha^{-1}). Giza 22 plants treated with 300 mg L^{-1} exhibited the highest mean values of pods per plant (112.00 pods plant^{-1}) and total seeds yield (3.07 Mg ha^{-1}).

Keywords: ***Glycine max*** **(L.), growth retardants, Merrill, protein percentage, productivity.**
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INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is an annual herbaceous legume, belonging to the family Fabaceae. Soybean one the oldest cultivated legume crop practiced by mankind (Thapar, 2021), and a nutritional staple for much of the world, it has become a top priority in the world economy. These seeds are known to contain protein in the range of 30–50%, and oil between 14-24%. Soybeans are widely used in human and animal nutrition. What distinguishes soybeans from other legumes is that their protein contains most essential amino acids necessary for human and animal growth, as well as certain vital vitamins, except for sulfur-containing amino acids such as cysteine and methionine (Saoudi, 2017). Additionally, soybean protein is superior to animal protein because it is free of cholesterol and fats (Ashi and Bashar, 2018).Soybean is considered one of the most important food and industrial crops, which has increased its global significance. Processed soybean-based foods have been found to offer protection against heart diseases (Carter and Wilson, 1998). Soybean seeds serve as a primary ingredient in animal feed production, particularly poultry feed, and are used in various human industries (Al-Soulagh *et al*, 2007). This crop is an important part of a large part of agricultural rotation, where its effects on soil quality and fertility support are evaluated using atmospheric nitrogen fixation It is (*Bradyrhizobiumjaponicum*), a nitrogen fixing root nodule bacterium that provides nutrients required for plant growth (Souza *et al*, 2015).Many researchers have conducted extensive studies to improve the cultivation of this crop. As a summer crop, soybean faces numerous challenges, particularly those related

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to the growth characteristics of its cultivars and their response to environmental conditions. Local studies have demonstrated that indeterminate cultivars are more suitable under Iraqi environmental conditions due to their adaptability to these conditions (Al-Jumaili, 2013). The compatibility between the cultivar, environmental conditions, and agricultural practices results in achieving high seed yield and quality, reflecting the effective utilization of these factors in favor of photosynthesis. Seed yield is closely related to the growth habit of the cultivars. Continued plant height increase often compromises pod formation, seed filling, and overall yield. When plant height exceeds 120 cm, the upper third of the plant tends to bear weak, sparse pods with delayed maturity. Moreover, plants become prone to lodging during the full maturity stage. To address this issue, the growth inhibitor ethephon was used. Ethephon reduces plant height as it acts as an antagonist to auxins or gibberellins when sprayed at the appropriate concentration and growth stage. This shift in growth promotes the development of more branches, accompanied by an increase in leaf area, which enhances light interception. Consequently, photosynthetic efficiency improves, resulting in greater productivity in terms of both quantity and quality (Bora and Sarma, 2004). The role of ethephon is to inhibit excessive growth and regulate the source-sink relationship by redistributing metabolic products among different plant parts. This enhances the plant's ability to utilize these products effectively, thereby improving yield and its components (Devi et *al*, 2011; Kaur *et al*, 2015). The current study focused on examining growth, yield and seed quality of some indeterminate soybean cultivars as influenced by the application of ethephon.

MATERIALS AND METHODS

The field experiment was conducted during the summer season of 2023 at one of the agricultural experimental fields, belonging to College of Agricultural Engineering Sciences, Station A, University of Baghdad / Jadiriyah. The coordinates of the site are 33.27°N, 44.38°E. The research was conducted to assess the effect of spraying different concentrations of the growth inhibitor ethephon on indeterminate soybean cultivars growth, yield and quality. The experiment was performed with a Randomized Completely Block Design (R.C.B.D) in a Split-Plot arrangement and three replicates, for 36 total experimental units. The main plots were the 3 soybean cultivars (Shaimaa, Giza 22, and Giza 111) and the subplots included the 3 concentrations of ethephon (100, 200, and 300 mg L^{-1}) in addition to a control treatment (spraying distilled water). Ethephon was applied at the beginning of the flowering stage (R1). Five soil samples were randomly collected from various locations within the field designated for planting, at 30 cm depth, prior to cultivation. The samples were thoroughly mixed, air-dried, ground, and sieved using a 2 mm mesh sieve. A single homogeneous composite sample was prepared and sent to the Soil Laboratory of the College of Agricultural Engineering Sciences, University of Baghdad, for the analysis of key chemical and physical properties required for the experimental field. These properties are summarized in Table (1).

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Table 1. Physical and chemical properties of the experimental soil before planting the 2023 season

Attribute	Value	Unit of Measurement
	Soil Separates	
Sand	128.6	g kg^{-1} soil
Clay	331.5	g kg^{-1} soil
Silt	539.9	g kg^{-1} soil
Soil Texture		Silty Clay Loam
Soil pH	7.21	-----
Electrical Conductivity (EC)	1.3	dS m^{-1}
Available Nitrogen	24.5	mg kg^{-1} soil
Available Phosphorus	4.62	mg kg^{-1} soil
Available Potassium	22.32	mg kg^{-1} soil
Available Boron	4.2	mg kg^{-1} soil
Organic Matter	0.8	%
	Dissolved Ions	
CaCO3	23.00	meq L^{-1}
Calcium (Ca)	8.13	meq L^{-1}
Magnesium (Mg)	6.19	meq L^{-1}
Sodium (Na)	1.12	meq L^{-1}
Chloride (Cl)	13.00	meq L^{-1}
Sulfate (SO4)	0.82	meq L^{-1}

Soil preparation operations were conducted before planting, including plowing, leveling, and smoothing using a moldboard plow. The experimental field was divided into plots according to the experimental field plan, with each plot containing three furrows. The area of each plot was 7.5 m^2 (2.5 m × 3 m), representing a single experimental unit. The distance between furrows was 75 cm, while the spacing between planting holes was 20 cm. A 50 cm gap was maintained between experimental units, resulting in a plant density of 66,666 plants ha^{-1} (4). A calibration irrigation was performed on the experimental field and left for 2–3 days to dry. Soybean seeds of the cultivars Shaimaa, Giza 22, and Giza 111 were sown on June 5, 2023, at a shallow depth of 2–3 cm, with 2–3 seeds per planting hole. Two weeks after emergence, the plants were thinned to one plant per hole. The experimental field was fertilized with nitrogen in the form of urea (46% N) at a rate of 160 kg N ha^{-1}, applied in two equal doses: the first at planting and the second at the beginning of the flowering stage. Triple superphosphate fertilizer (46% P_2O_5) was applied to the field at a rate of 80 kg ha^{-1} as a single dose before planting (Ali, 2012). The experiment also included crop maintenance practices such as weeding and irrigation as needed. The required concentrations of the growth inhibitor ethephon were prepared in the laboratories of the postgraduate studies at the College of Agricultural Engineering Sciences, University of Baghdad, as follows:

The necessary volumes of the ethephon solution (48%) were measured and transferred into volumetric flasks. Each volume was then diluted to one liter with distilled water to achieve the spray concentrations of 100, 200, and 300 mg L^{-1}. The ethephon was applied to the plant foliage twice: the first application at the beginning of flowering (R1) and the second one week after the first spray. The spraying was carried out early in the morning, ensuring that the atmosphere was free of dust. A 16-liter capacity backpack sprayer was used for the application to enhance absorption efficiency and reduce the surface tension of water, 2–3 drops of dishwashing liquid per liter were added to the solution as a surfactant, ensuring complete wetting of the plant foliage. For the control treatment, plants were sprayed with distilled water only.

RESULTS AND DISCUSSION

Number of pods per plant (pods plant^{-1}): the results show a significant effect of soybean cultivars and ethephon concentrations on the number of pods per plant (Table 2). The cultivar Giza 22 recorded the highest mean

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number of pods per plant at 96.16 pods plant^{-1}, followed by Giza 111 with an mean of 90.51 pods plant^{-1}. In contrast, the cultivar Shaimaa recorded the lowest mean of 84.94 pods plant^{-1}. The superiority of Giza 22 in the number of pods per plant may be attributed to its genetic potential. This result aligns with the findings of (Dawood and Jaddoa, 2023; Al-Turaihi, 2024), who reported significant differences among soybean cultivars in the number of pods per plant. The results also indicate that ethephon application significantly affected this trait. Spraying ethephon at a concentration of 300 mg L^{-1} resulted in the highest mean number of pods per plant (104.9 pods plant^{-1}), while the control treatment recorded the lowest mean (77.51 pods plant^{-1}). This increase can be attributed to enhanced branching, leaf area, and its index (Tables 3, 4, and 5), which improved photosynthetic efficiency and its metabolic products. Furthermore, the ethylene released from ethephon application may have contributed to early pod development by reducing flower and pod drop, encouraging better pod setting and growth, and thus increasing the number of pods per plant. This conclusion is supported by the positive correlation between the number of pods per plant and plant height, number of branches, and leaf area and its index. These results are consistent with those of (Bramhankar *et al*, 2018; Al-Darraji, 2019; Al-Karawi, 2022) who noted significant effects of ethephon concentrations on the number of pods per soybean plant. Results revealed a significant interaction among soybean cultivars and ethephon concentrations. Plants of the cultivar Giza 22 sprayed with 300 mg L^{-1} ethephon recorded the highest mean number of pods per plant (112.00 pods plant^{-1}) compared to other treatments. This can be attributed to the higher effectiveness of the 300 mg L^{-1} concentration in increasing branching in Giza 22 plants, which consequently increased the number of pods per plant.

Table 2. Effect of Ethephon and cultivars in number of pods per plant (pods plant^{-1}) of soybean for the year 2023

Cultivars	Ethephon Concentrations mg L^{-1}				Mean cultivars
	0	100	200	300	
Shaimaa	73.40	79.58	89.39	97.39	84.94
Giza 22	81.97	89.62	101.1	112.00	96.16
Giza 111	77.16	84.72	94.81	105.40	90.51
Mean of Concentrations	77.51	84.64	95.09	104.90	
$LSD_{0.05}$ Cultivars			1.59		
$LSD_{0.05}$ Concentration			70.9		
$LSD_{0.05}$ Interaction			1.90		

Number of seeds per pod (seeds pod^{-1})

The results indicate non-significant effect of soybean cultivars on the number of seeds per pod. However, ethephon concentrations significantly influenced this trait. Results shows that spraying soybean plants with ethephon at a concentration of 300 mg L^{-1}resulted in the highest mean number of seeds per pod (2.93 seeds pod^{-1}), while the control treatment recorded the lowest mean (2.32 seeds pod^{-1}). This improvement could be attributed to the role of ethephon in regulating plant growth and reducing competition among plant parts for metabolic products by redistributing them more evenly between vegetative and reproductive parts. This balanced allocation positively impacted the number of seeds per pod. These findings align with the results of (Bramhankar *et al*, 2018; Al-Darraji, 2019; Al-Karawi, 2022), they reported significant differences in the number of seeds per pod in response to varying ethephon concentrations in soybean plants. The results revealed no significant interaction between soybean cultivars and ethephon concentrations.

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Table 3.Effect of Ethephon and cultivars in number of seeds per pod (seeds pod⁻¹) of soybean for the year 2023

Cultivars	Ethephon Concentrations mg L^{-1}				Mean cultivars
	0	100	200	300	
Shaimaa	2.28	2.39	2.58	2.89	2.53
Giza 22	2.35	2.46	2.57	2.97	2.59
Giza 111	2.32	2.43	2.64	2.93	2.58
Mean of Concentrations	2.32	2.43	2.60	2.93	
$LSD_{0.05}$Cultivars	N.S				
$LSD_{0.05}$Concentration	0.05				
$LSD_{0.05}$Interaction	N.S				

100-Seed weight (g)

The results reveals significant effects of soybean cultivars and ethephon concentrations on the 100-seed weight. The cultivar Shaimaa recorded the highest mean 100-seed weight of 15.88 g, followed by Giza 111 with an mean of 14.83 g. In contrast, Giza 22 recorded the lowest mean of 13.95 g. The superiority of Shaimaa in 100-seed weight can be attributed to its lower number of pods per plant (Table 2), making the plants of this cultivar more efficient in allocating photosynthetic products to sinks (seeds), thereby increasing their weight. These results are consistent with the findings of (Al-Qaisi, 2012; Al-Muainee and Al-Ubaidi, 2018; Elsahookii and Jayad, 2023; Al-Turaihi, 2024), who reported significant differences among cultivars in the 100-seed weight of soybean plants. The results showed that spraying soybean plants with ethephon significantly affected the 100-seed weight. The control treatment recorded the highest mean (15.63 g), while spraying with 300 mg L^{-1}ethephon resulted in the lowest mean 100-seed weight (13.90g). The reduction in 100-seed weight in plants treated with 300 mg L^{-1}ethephon could be attributed to the treatment's superiority in the number of pods per plant (Table 2). Results indicate a significant negative correlation between 100-seed weight and the number of pods per plant. These findings align with those of (Kaur *et al*, 2015; Al-Darraji, 2019; Al-Karawi, 2022), they reported significant effects of ethephon concentrations on the 100-seed weight of soybean plants. The results show no significant interaction among soybean cultivars and ethephon concentrations for this trait.

Table 4. Effect of Ethephon and cultivars in 100-seed weight (g)of soybean for the year 2023

Cultivars	Ethephon Concentrations mg L^{-1}				Mean cultivars
	0	100	200	300	
Shaimaa	16.55	16.20	15.85	14.92	15.88
Giza 22	14.83	14.25	13.91	12.85	13.96
Giza 111	15.50	15.16	14.74	13.93	14.83
Mean of Concentrations	15.63	15.20	14.84	13.90	
$LSD_{0.05}$Cultivars	0.23				
$LSD_{0.05}$Concentration	0.27				
$LSD_{0.05}$Interaction	N.S				

Total seeds yield (Mg ha^{-1})

Total seed yield represents the combined result of the number of pods per plant, the number of seeds per pod, and seed weight. These components are the final outcome of the biochemical activities occurring within the plant throughout its lifecycle and are influenced by various environmental and genetic factors. The results indicate significant effects of soybean cultivars and ethephon concentrations on total seeds yield (Table 5). Results show that the cultivar Giza 22 recorded the highest mean total seed yield of 2.51 Mg ha^{-1}, followed by Giza 111 with an mean of 2.43 Mg ha^{-1}. In contrast, the cultivar Shaimaa recorded the lowest mean total seed yield of 1.65 Mg ha^{-1}. The superiority of Giza 22 in total seed yield can be attributed to its

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higher number of pods per plant (Table 2), which contributed to increased seed yield per unit area. These findings are consistent with those of (17 and 20), who reported significant differences among cultivars in total seed yield of soybean plants. The results indicate that spraying soybean plants with ethephon significantly affected total seeds yield. The treatment with 300 mg L^{-1}ethephon recorded the highest mean total seed yield of 2.59 Mg ha^{-1}, while the control treatment recorded the lowest mean of 1.83 Mg ha^{-1}. This increase can be attributed to the treatment's superiority in the number of pods per plant (Table 2). The results confirm a significant positive correlation between total seed yield and the number of pods per plant. These findings are in agreement with those of. (Bramhankar *et al*, 2018; Al-Darraji, 2019; Al-Karawi, 2022), who also reported significant differences in total seed yield with varying ethephon concentrations in soybean plants.The results show significant differences between soybean cultivars and ethephon concentrations for this trait. The plants of the cultivar Giza 22, sprayed with 300 mg L^{-1} of ethephon, achieved the highest mean total seed yield of 3.07 Mg ha^{-1} compared to other treatments. This interaction can be explained by the high effectiveness of the 300 mg L^{-1} concentration on Giza 22, as its genetic and physiological characteristics differ from other cultivars, making it more responsive to the high ethephon concentration.

Table 5.Effect of Ethephon and cultivars in total seed yield (mg ha^{-1}) of soybean for the year 2023

Cultivars	Ethephon Concentrations mg L^{-1}				Mean cultivars
	0	100	200	300	
Shaimaa	1.46	1.65	1.72	1.75	1.65
Giza 22	2.03	2.29	2.64	3.07	2.51
Giza 111	2.00	2.17	2.58	2.95	2.43
Mean of Concentrations	1.83	2.04	2.31	2.59	
$LSD_{0.05}$Cultivars			0.36		
$LSD_{0.05}$Concentration			0.15		
$LSD_{0.05}$Interaction			0.38		

Protein percentage in seeds (%)

The results indicate significant effects of soybean cultivars and ethephon concentrations on the protein percentage in seeds (Table 6). The cultivar Shaimaa recorded the highest mean protein percentage (38.17%), followed by Giza 111 with an mean of 37.22%. In contrast, Giza 22 recorded the lowest mean protein percentage (36.24%). This variation may be attributed to seed composition, which depends on the balance of oil and protein content, both in quantity and quality. Typically, an increase in oil percentage is associated with a decrease in protein percentage due to the inverse relationship between these two traits. This balance is influenced by environmental, genetic, and interactional factors (Ngalamu *et al*, 2013). These findings are consistent with those of (Al-Turaihi,2024), who reported significant differences among cultivars in the protein percentage of soybean seeds. The results indicate that spraying soybean plants with ethephon significantly affected the protein percentage in seeds. Spraying with 300 mg L^{-1} ethephon resulted in the highest mean protein percentage (40.73%), while the control treatment recorded the lowest mean (34.00%). This increase can be attributed to the role of ethephon at an appropriate concentration in promoting protein synthesis by regulating RNA synthesis and producing specific protein enzymes, particularly protease, which leads to an increase in protein content in the seeds (Reddy *et al*,2009). These findings are consistent with those of (Al-Darraji,2019, Al-Karawi,2022 and . Sahane *et al*,2015), who also reported significant effects of ethephon concentrations on the protein percentage in soybean seeds.The results show no significant interaction between soybean cultivars and ethephon concentrations for this trait.

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Table 6. Effect of Ethephon and cultivars in protein percentage in seeds (%)of soybean for the year 2023

Cultivars	Ethephon Concentrations mg L^{-1}				Mean cultivars
	0	100	200	300	
Shaimaa	35.04	36.97	39.14	41.54	38.17
Giza 22	32.89	34.99	37.14	39.98	36.25
Giza 111	34.08	35.94	38.21	40.68	37.23
Mean of Concentrations	34.00	35.97	38.16	40.73	
$LSD_{0.05}$Cultivars			0.30		
$LSD_{0.05}$Concentration			0.33		
$LSD_{0.05}$Interaction			N.S		

CONCLUSION

This study revealed that the application of ethephon significantly enhanced key growth and yield traits of soybean. Among the cultivars, Giza 22 outperformed others in pod number and total seeds yield, while Shaimaa recorded the highest 100-seeds weight and protein percentage. Spraying ethephon at 300 mg L^{-1} resulted in superior plant performance, particularly in pod formation, seeds yield, and protein content, indicating its potential to optimize growth and productivity under Iraqi environmental conditions. These findings emphasize the importance of cultivar selection and precise ethephon application to maximize soybean yield and quality. Future studies should explore long-term effects and economic viability to refine soybean production strategies further.

CONFLICT OF INTEREST

The author declares that they have no conflicts of interest.

DECLARATION OF FUND

The authors declare that they have not received a fund.

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تأثير رش الأثيفون في حاصل البذور ومكوناته لأصناف مختلفة من فول الصويا

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قسم المحاصيل الحقلية/ كلية علوم الهندسة الزراعية/ جامعة بغداد, العراق

المستخلص

أُجريت تجربة حقلية في حقول كلية علوم الهندسة الزراعية – جامعة بغداد خلال الموسم الصيفي لعام 2023 لدراسة تأثير رش الأثريل على نمو وحاصل ونوعية أصناف فول الصويا غير محدودة النمو. استعمل تصميم القطاعات الكاملة المعشاة(R.C.B.D)وفق ترتيب الألواح المنشقة بثلاثة مكررات. شملت التجربة ثلاثة تراكيب وراثية (شيماء، جيزة 22، وجيزة 111) وأربع معاملات رش (100، 200، 300 ملغم لتر$^{-1}$، والمقارنة بالماء المقطر.أظهرت النتائج تفوق الصنف جيزة 22 بأعلى متوسط لعدد القرنات (96.16 قرنة نبات$^{-1}$) وحاصل البذور الكلي (2.51 ميغاغرام هـ$^{-1}$)، بينما سجل الصنف شيماء أعلى متوسط لوزن 100 بذرة (15.88 غم) والنسبة البروتين (38.14%). أثر تركيز 300 ملغم لتر$^{-1}$ بشكل إيجابي على عدد القرنات (104.90 قرنة نبات$^{-1}$)، عدد البذورفي القرنة (2.93 بذرة قرنة$^{-1}$)، وحاصل البذور (2.59 ميغاغرام هـ$^{-1}$). كما حققت نباتات جيزة 22 عند تركيز 300 ملغم لتر$^{-1}$ أعلى متوسط (112.00 قرنة نبات$^{-1}$ و3.07 ميغاغرام هـ$^{-1}$.

الكلمات المفتاحية: *Glycine max* (L.) Merrill, معيقات النمو، الإنتاجية، نسبة البروتين.

*جزء من رسالة ماجستير للباحث الاول.