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Impact of some growth regulators on growth and productivity of broad bean plant grown under Upper Egypt conditions

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Abstract

Two filed experiments were conducted at winter successive two seasons of 2020/2021 and 2021/2022 in the private Farm of Al-Wastta village, All- Fatah center, Assiut Governorate, Egypt. The experiments were carried out to study the effect of some growth regulator concentrations treatments on productivity of broad bean (*Vicia faba* L.) plants under Assiut Governorate conditions. The experiment was laid out in split plot design with three replicates. Growth regulators GR (salicylic acid (SA), gibberellic acid (GA) and naphthalene acidic acid (NAA)) were put in the main plot, while the concentrations (25, 50 and 75 ppm) were allocated in sub-plot. The results show that all applications of GR and concentrations increased all vegetative characters (i.e., plant height, number of branches and leaves) as well as, yield and its components (i.e., number of pods / plant, number of seeds / pod, pods weight / plant (g), number of pods / plot, pods weight / plot (kg), pod weight (g), pod height (cm), plant fresh weight (kg) and total yield (ton / feddan (4200 m^2)) of all studied broad bean, comparing to untreated plants. The results also show the protein % in broad bean seeds were increased by increasing all GR concentration under the study in both seasons. Foliar application by NAA at a rate of 75 ppm gave the maximum protein values: 28.43 and 28.89% in both seasons, respectively. In conclusion, a superiority effect happened on all parameters under study for the plants treated with NAA following with GA and lastly SA as compared to control treatment. Generally, the most suitable treatment, which realizing the highest yield of broad bean seeds and protein % was connected with the treatment of 75 ppm of NAA.

Keywords: Broad bean, organic acids, growth regulators, growth, yield and productivity.

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1. Introduction

Faba bean (*Vicia faba* L.) is the most important food legume crop in Egypt, as a source of plant protein, and plays a good role in farming, as a break crop in intensive cereal systems. The planted area, in Egypt, was about 113.810 feddan (4200 m^2) with an average productivity of 9.2 ardebs /feddan (ardeb=160 kg), during the last five years. There is a need to improve productivity and total production to meet the increasing demand for faba bean in Egypt. This could be achieved through enhancing crop breeding and agriculture practice (FAO, 2019). Broad bean is nutritionally important vegetable all over the world, containing 20-36% protein for human and animal consumption (Crepon *et al*. 2010). Also, Broad beans (*Vicia faba* L.) are one of the most strategic legume crops in Egypt, due to their importance as a major part of the Egyptian local dishes (Hegab *et al*., 2014). Egypt is one of the eight main producers of broad beans (150,000 tons that are equivalent to 3.46% of the global production), however, this amount isn't sufficient for consumed and Egypt being imported from abroad (Rawal and Navarro, 2019). The plant growth regulators (PGRs) are a wide category of compounds that can promote, inhibit or change plant physiological or morphological processes at very low concentrations. Thus, the use of PGRs has become an important component of the agro-technical procedures for most cultivated species and especially for fruit plants (Monselise, 1979). Rasheed Sanaa (2018) showed that treating of broad bean plant with salicylic acid (especially 100 g L^{-1}) led to significant increases pods weight g, number of branches per plant, pods weight (g), pod yield g $plant^{-1}$, total yield ton $donum^{-1}$, number of seed per pod, seed weight g, weight of 100 seed g, green seed yield g $plant^{-1}$ and total seed yield ton $donum^{-1}$. Kadhim (2022) indicated that salicylic acid at 100 g/L increased significantly all the parameters (plant height, branches number, leaf area, and chlorophyll content) and yield and yield components (pods/plant, seed number /pod, 100 seed weight, pods yield (kg/ha) and protein content of seed). Noor *et al*., (2017) found that applied gibberellin (GA3) treatments to French bean plants significantly increased plant height than the control plants. GA3 with 30 to 90 ppm significantly increased number of branches and leaves, leaf area, leaf area index (LAI), leaf dry matter and total dry matter at different growth stages. Rathore *et al*. (2022) indicated that foliar spraying of 120 ppm GA3 tended to produce plant with maximum height (116.4 cm), number of branches/plant (6.3), pod length (7.5 cm), number of seeds/pod (4.6) as well as early 50% flowering (57.3 days) whereas, spraying of 40 ppm NAA exhibited the maximum pod width (1.3 cm), fresh pod weight (4.6 g), number of pods/plant (87.5) as well as fresh pod yield (105.0 q ha^{-1}) as compared to other treatments. Teama *et al*. (2023) showed that the tested growth regulators (indole acetic acid, gibberellin acid, and salicylic acid) had a significant effect on the number of pods per plant, 100-seed weight, seed weight per plant, and seed yield of faba bean per acre in both growing seasons. Furthermore, bean plants sprayed with 200 ppm gibberellic acid or salicylic acid yielded the highest average values for the aforementioned traits in both seasons. Rathore *et al*. (2022) found that spraying of 40 ppm NAA exhibited the maximum pod width (1.3 cm), fresh pod weight (4.6 g), number of pods/plant (87.5) as well as fresh pod yield of broad bean (105.0 q ha^{-1}) as compared to other treatments. The spraying of NAA was found superior in terms of yield and yield attributes as well as benefit cost ratio followed by GA3 and salicylic acid. Sharief and El-hamady (2017) stated that Naphthalene Acetic Acid foliar spraying up to 60 ppm exceeded of total chlorophyll, plant height (cm), branches number/plant, number of shedding flowers, pods number/plant, seeds number/pod, seeds number/plant, seed yield (g) /plant, 100-seed weight (g), seed yield (ton/ha) and protein % by 11.47, 23.92, 92.88, 20.53, 11.87, 23.48, 14.16, 24.91, 26.15 and 13.23%, respectively as the average of both seasons. It could be recommended that foliar spraying of Naphthalene acetic acid up to 60 ppm and Kin of 45 ppm improved seed yield/ha by 38.2% compared without foliar application. Thus, increasing broad bean production is a main target in the Egyptian agricultural strategy in order to face the demand of the growing population. Thus, the objective of this study was to investigate the growth, yield and its components of broad bean plants as affect by foliar application of organic acids and growth regulators under Assiut conditions, Egypt.

2. Materials and methods

2.1 Experimental site and treatments description

Two filed experiments were conducted at winter successive two seasons of 2020/2021 and 2021/2022 at a private farm of Al-Wastta village, All-Fatah center, Assiut governorate, Egypt. The experiments were carried out to study the effect of some growth regulator treatments on productivity of broad bean (*vicia faba* L.) plants under Assuit governorate conditions. The experiment was laid out in split plot design with three replicates. Growth regulators salicylic acid (SA), gibberellic acid (GA) and naphthalene acidic acid (NAA) were put in the main plot, while the concentrations (25, 50 and 75 ppm) were allocated in sub-plot. Foliar application was done after 30, 45 and 60 days after seeds sowing. Nitrogen fertilizer was added as ammonium nitrate (33.5% N) with four rates (0, 10, 20 and 30 kg N $feddan^{-1}$) in three times (21, 45 and 65 days) after seeds planting. All farming processes were carried out before planting. Super phosphate (15.5% P_2O_5) was applied at a rate of 100 kg super phosphate $feddan^{-1}$ during tillage of soil. Seeds of faba bean were sown on 1st November and harvesting was done on 1st April in both seasons. Each experimental plot unit was 10.5 m^2 / feddan at row-to-row distance of 50 cm. Two to three of seeds were sown in holes was 20 cm. After 21 days of sowing, the plants of each hole were thinned to one plant. Potassium sulphate (48% K_2O) was applied at a rate of 50 kg feddan^{-1} on two equal doses after 20 and 40 days from sowing. Soil samples were collected from all studied treatments at a depth of (0–30 cm) to determine some soil physical and chemical characteristics. Soil pH was determined in 1:2.5 soils: water suspensions according to the standard method of Richards (1954). Total soluble salts were measured in soil paste extract as described by Jackson (1973). Phosphorus was determined calorimetrically and potassium was determined using flame- photometer according to Jackson (1973). Some physical and chemical properties of the experimental soil were shown in Table (1).

Table (1): Some physical and chemical properties of the soil in both seasons.

Season	Sand (%)	Silt (%)	Clay (%)	Texture	pH 1:1	ECe dS/m	Total $CaCO_3$ (%)
2020/2021	19.3	31.0	49.7	Clay	7.59	1.44	3.10
2021/2022	21	29.4	49.6	Clay	8.06	1.32	3.75
		Total N (%)	Available nutrients ppm				
			P	K	Fe	Mn	Zn
		1.85	16.7	354	10.7	9.3	1.0
		1.80	14.8	325	8.6	8.0	1.1

2.2 Data recorded

A random sample of ten plants from each plot was taken at 90 days after sowing to the laboratory where the following characteristics were recorded.

2.2.1 Vegetative Growth Measurements

The following characteristics were recorded: Plant height (cm), number of leaves / plant, and number of branches / plant.

2.2.2 Yield Measurements

The following characteristics were recorded: Number of pods / plant, number of seeds / pod, pods weight / plant (g), number of pods / plot, pods weight/ plot (kg), pod weight (g), pod height (cm), plant fresh weight (kg), and total yield (ton / feddan).

2.2.3 Chemical analysis

2.2.3.1 Protein (%)

Nitrogen was determined by Kjeldahl method (Page *et al.*, 1982). Protein percentage of seeds was calculated by multiplying the nitrogen percentage by the factor 6.25 described by Hymowitz *et al*. (1972).

2.2.4 Data analysis

Analysis of variance relevant to split-plot experiments as described by Gomez and Gomez (1984) was used. The data of the growth hormones and water regimes gave some error degrees of freedom suitable to conduct a valid ‘F’ significance test. In such a case, ‘The Least Significant Difference’ (LSD 0.05) was used for means comparisons (Steel and Torrie, 1980).

3. Results and discussions

3.1 Vegetative growth parameters

3.1.1 Plant height (cm)

Data presented in Table (2) indicated that different growth regulators (GR) and their concentrations had a significant effect on plant height during both the 2020/2021 and 2021/2022 growing seasons. Results showed that significant differences in mean plant height between the three studied growth regulators (GR). Foliar application with NAA recorded the maximum mean values of plant height than both SA and GA in both seasons, respectively. Also, the increase percentages of plant height due to NAA surpassed plant height of both SA and GA in the 1st and 2nd season, respectively by (12.06 and 14.22%) and (10.45 and 13.52%) in both seasons, respectively. Application of different levels of NAA had significant impact on all the growth and yield characters. Similar result was revealed by Ahmad *et al*. (2024) who reported that highest plant height of brinjal was significantly increased with 90 ppm of NAA. The increase in growth parameters might be attributed to better nutritional environment for plant growth and development due to increased level of NAA at 90 ppm. Application of NAA has been reported to help in cell elongation resulting in increased growth parameters (Patel *et al.*, 1997). In this respect, Sharief and El-Hamady (2017) found that foliar application of NAA levels of to 60 ppm significantly increased plant height (cm) by 11.47 as the average of both seasons. They could be recommended that foliar spraying of Naphthalene Acetic Acid up to 60 ppm improved seed yield/ha by 38.2% compared without foliar application. All GR significantly increased plant height as reported by El-Emshaty *et al*. (2021) Addition of SA (1.0 ppm) and/ or GA (150 ppm) to faba bean at 14-21 days' irrigation period show maximum increase in plant characteristics (i.e. plant height). Atab *et al*. (2023) indicated that spraying broad bean plants with salicylic acid was significantly excelled on 200 mg L^{-1} in the studied traits for plant height (97.08 cm). Kadhim (2022) Salicylic acid at level (100) g/L gave the highest means of plant height (142.27 cm), while control recorded the lowest means (137.10 cm). Regarding GR concentrations, results revealed that all GR increased plant height with increasing the concentration of each one. The tallest broad bean plants were observed when NAA was foliar applied at 75 ppm with increasing percentages over the control treatment by (27.1 and 31.04%) in the 1st and 2nd seasons, respectively. Fadhil and Almasoody (2019) indicated that gibberellic acid at 300 mg l^{-1} gave the highest average of plant height (78.89 cm) compared to the non-adding treatment which gave the lowest average in this trait amounted (70.78 cm). This is due to the role of gibberellin in stimulating the process of the plant elongation, wherever the concentration of gibberellin increased, the plant height was increased. These results agree with Saleh and Abdul (1980). The increase in plant height is due to the effect of gibberellic acid in increasing cell division and enlargement, in adding to stimulating growth and cell expansion (Saleh, 1990). The interaction between GR and their concentrations found that maximum plant height recorded by foliar application of NAA at a concentration of 75 ppm in both seasons, respectively with values of (141.6 and 150.3 cm) in the 1st and 2nd seasons, respectively. In this respect, Atab *et al*. (2023) indicated that spraying broad bean plants with salicylic acid was significantly excelled on 200 mg L^{-1} in the studied traits for plant height (97.08 cm) (Kadhim, 2022). Salicylic acid at level 100 g/L gave the highest means of plant height (142.27 cm), while control recorded the lowest means (137.10 cm). Rathore *et al*. (2022) indicated that foliar spraying of 120 ppm GA3 tended to produce plants with maximum height (116.4 cm).

Table (2): Effect of growth regulators, concentrations and their interactions on plant height of broad bean plants (*Vicia faba* L.) in 2020/2021 and 2021/2022 seasons.

Treatments (A) / Concentration (B)	First season				Second season			
	SA	GA	NAA	Mean	SA	GA	NAA	Mean
Control	102.3	102.3	102.3	102.3	103.4	103.4	103.4	103.4
25 ppm	100.2	109.1	120.4	109.9	105.2	111.2	127.6	114.7
50 ppm	115.1	110.8	130.1	118.7	119.3	115.3	139.1	124.6
75 ppm	123.4	125.3	141.6	130.1	127.5	128.6	150.3	135.5
Mean	110.3	111.9	123.6		113.9	114.6	130.1	
L.S.D 0.05 A	1.96				2.07			
L.S.D 0.05 B	2.11				2.23			
L.S.D 0.05 AB	2.37				2.45			

3.1.2 Number of leaves /plant

Data on the main values of growth regulator (GR) are presented in Table (3). Data demonstrated in Table (3) stated that main values of number of leaves /plant were highly significantly affected by GR and their concentrations in both seasons. The obtained results in Table (3) showed that NAA recorded the maximum values of number of leaves /plant (85.32 and 88.60) While, foliar application with SA and GA recorded the minimum values of number of leaves /plant (52.68 and 56.35) and (61.04 and 63.83) in the 1st and 2nd season, respectively. Also, NAA significantly increased number of leaves /plant over SA application by 61.95% and 57.23% and over GA by 39.77% and 38.75%. Also, foliar application with NAA gave the highest number of leaves /plant compared to other GR under the study in both seasons. Fadhil and Almasoody (2019) confirmed that there were significant differences in the genotypes in the number of leaves in the broad bean plant. Local genotypes gave the highest average amounted of 7.75 on other genotypes. Ahmad *et al*. (2024) revealed that the maximum number of leaves was observed with NAA at 90 ppm recorded 39.90, 76.04, and 100.06 at 30, 60 and 90, DAT respectively over the rest level of NAA, except 30 and 60 DAT which was significantly superior over rest of the treatment whereas the difference between NAA at 90 ppm and NAA at 70 ppm was found non-significant. Crop without NAA treatment produced significantly the lowest number of leaves (32.63, 55.17, and 80.05) at 30, 60 and 90 days, respectively. Data in Table (3) showed that main values of number of leaves /plants highly significantly affected by the concentration of all GR under the study in comparison to the control treatment in both seasons. Also, number of leaves /plant significantly increased with increasing concentrations of GR. This held true in both seasons. The highest number of leaves /plant values was obtained (76.04 and 79.37) due to 75 ppm foliar application of NAA. While the minimum number of leaves /plant values was recorded (53.11 and 57.25) due to the control. Foliar application of NAA at 75 ppm significantly increased number of leaves /plant by (43.17 and 38.63%) over the control treatment. Increased vegetative growth of brinjal due to NAA application is in close conformity with the findings of (Athaneria *et al*., 2011; Patel *et al*., 2012). Regarding the interaction between GR and their concentration, results recorded in Table (3) found that number of leaves /plant significantly affected by the second interaction (A × B) in both seasons. The maximum values of number of leaves /plant recorded (102.4 and 105.3) due to the applied 75 ppm of NAA in both seasons, respectively. Similar results were obtained by Fadhil and Almasoody (2019) and Ahmad *et al*. (2024).

Table (3): Effect of growth regulators, concentrations and their interactions on number of leaves /plant of broad bean plants (*Vicia faba* L.) in 2020/2021 and 2021/2022 seasons.

Treatments (A) / Concentration (B)	First season				Second season			
	SA	GA	NAA	Mean	SA	GA	NAA	Mean
Control	53.11	53.11	53.11	53.11	57.25	57.25	57.25	57.25
25 ppm	49.12	59.32	89.36	65.93	52.54	61.17	92.37	68.69
50 ppm	51.24	63.25	96.41	70.30	54.36	65.33	99.46	73.05
75 ppm	57.26	68.47	102.4	76.04	61.24	71.56	105.36	79.37
Mean	52.68	61.04	85.32		56.35	63.83	88.60	
L.S.D 0.05 A	2.98				3.12			
L.S.D 0.05 B	3.41				3.64			
L.S.D 0.05 AB	3.87				4.02			

3.1.3 Number of branches / plants

Data of the main values of growth regulator (GR) are presented in Table (4). Data demonstrated in Table (4) stated that main values of number of branches /plant highly significantly affected by GR and their concentrations in both seasons. The obtained results in Table (4) showed that NAA recoded the maximum values of number of branches /plant (6.385 and 6.528) While, foliar application with SA and GA recorded the minimum values of number of branches /plant (5.019 and 5.169) and (5.567 and 5.757) in the 1st and 2nd seasons, respectively. Also, NAA significantly increased number of leaves

/plant over SA application by 27.21 and 26.29, and over GA by 14.69 and 13.39. Also, foliar application with NAA gave the highest number of branches /plant compared to other GR under the study in both seasons. In this respect, Sharief and El-Hamady (2017) found that foliar application of NAA levels of to 60 ppm significantly increased branches number /plant, by 23.92%. They recommended that foliar spraying of naphthalene acetic acid up to 60 ppm improved seed yield/ha by 38.2% compared without foliar application. Moreover, Ahmad *et al*. (2024) indicated that the maximum number of branches were recorded (18.59, 19.16, 20.16 cm) at 30, 60 and 90, DAT respectively was observed with NAA at 90 ppm which was significantly superior over the rest of at all stages except 90 DAT where NAA at 90 ppm and NAA at 70 ppm was found non-significant. The lowest number of branches (11.00, 12.42, and 14.95 cm) at 30, 60, 90 days respectively was recorded under no NAA application. Data show (Table 3) that main values of number of leaves /plant highly significantly affected by the concentration of all GR under the study in comparison to the control treatment in both seasons. Also, number of branches /plants significantly increased with increasing concentrations of GR. This held true in both seasons. The highest number of branches /plant values was obtained (6.480 and 6.575) due to 75 ppm foliar application of NAA. While the minimum number of branches /plant values was recorded (4.231 and 4.572) due to the control. Foliar application of NAA at 75 ppm significantly increased No. of branches /plant by (53.15 and 43.81%) over the control treatment. The increase in number of leaves /plant due to increasing foliar application of GR was investigated by several researchers; Fadhil and Almasoody (2019) showed that the growth regulator gibberellin gave the highest average No. of branches control. Atab *et al*. (2023) indicated that spraying broad bean plants with salicylic acid was significantly excelled on 200 mg L^{-1} in the studied traits for the number of branches (10.87 branch $plant^{-1}$). Regarding the interaction between GR and their concentration, results recorded in Table (4) found that No. of branches /plant significantly affected by the second interaction (A × B) in both seasons. The maximum values of No. of leaves /plant recorded (7.364 and 7.432) due to the applied 75 ppm of NAA in both seasons, respectively. Similar results were in agreement with Rasheed Sanaa (2018) treating of broad bean plant with salicylic acid especially (100 g L^{-1}) led to significant increases No. of branches per plant. Kadhim (2022) reported that higher mean of this trait (18.76 branches per plant) was recorded by 100 g/L salicylic acid and the control gave the lowest mean (13.90) branches per plant. Rathore *et al*. (2022) indicated that the growth parameters like the foliar spraying of 120 ppm GA3 tended to produce plant with maximum number of branches/plant (6.3).

Table (4): Effect of growth regulators, concentrations and their interactions on number of branches /plant of broad bean plants (*Vicia faba* L.) in 2020/2021 and 2021/2022 seasons.

Treatments (A) / Concentration (B)	First season				Second season			
	SA	GA	NAA	Mean	SA	GA	NAA	Mean
Control	4.231	4.231	4.231	4.231	4.572	4.572	4.572	4.572
25 ppm	4.861	5.762	6.912	5.845	4.942	5.861	6.984	5.929
50 ppm	5.252	5.931	7.032	6.072	5.342	6.121	7.125	6.196
75 ppm	5.733	6.342	7.364	6.480	5.821	6.472	7.432	6.576
Mean	5.019	5.567	6.385		5.169	5.757	6.528	
L.S.D 0.05 A	0.107				0.115			
L.S.D 0.05 B	0.142				0.156			
L.S.D 0.05 AB	0.156				0.167			

In summary, main values of vegetative growth parameters including, plant height, number of leaves /plant and number of branches /plants highly significantly affected by GR and their concentrations in both seasons. All growth parameters increased with increasing the concentration of al GR in both seasons. The highest values of plant height, number of leaves and number of branches were recorded to foliar application of NAA at a concentration of 75 ppm in both seasons.

3.2 Yield components

3.2.1 Number of pods /plant

Average of number of pods /plant of broad bean grown at Assiut Governorate as affected by GR and their interaction effects in 2021/2022 and 2022/2023 seasons are presented in Table (5). Obtained data of Table (5) indicated that number of pods/plant was affected significantly by GR. Number of pods /plant under the study was significantly higher under the foliar application of NAA compared with the other GR under the study in both seasons. The number of pods/plant values due to foliar application of NAA recorded (14.81 and 16.21) compared to SA or even GA application in both seasons, respectively. Rathore *et al*. (2022) indicated that the growth parameters like, number of pods/plant spraying of 40 ppm NAA exhibited the maximum number of pods/plant (87.5). Moreover, Sharief and El-hamady (2017) found that foliar application of NAA levels of to 60 ppm significantly increased number/pod naphthalene acetic acid foliar spraying up to 60 ppm exceeded of pods number /plant, seeds number/pod by 92.88 as the average of both seasons. It could be recommended that foliar spraying of naphthalene acetic acid up to 60 ppm improved seed yield/ha by 38.2% compared without foliar application. Concerning the main effect of GR-concentration (Table 5), results revealed that, number of pods/plant under the study were significantly increased with increasing the concentration in both seasons. Application of NAA at a rate of 75 ppm increased number of pods/plant by 46.26 and 43.85% compared to the control in both seasons, respectively. Fadhil and Almasoody (2019) showed that spraying plants with GA at 300 mg L^{-1} gave the highest average of no of pods/plant 16.78 pods, compared to the no adding treatment. Jasim and Muhsen (2014) reported that all spraying treatments led to a significant increase in pods number plant^{-1} of mung bean plants compared to control, and spraying SA with high concentration (1 mM/L) was superior compared to other spraying, which gave 14.5 with a percentage increase of 36.5% compared to control that gave the lowest value of 11.5. Moreover, interaction effects between GR and their concentration (Table 5) indicated that spraying broad bean by NAA recorded the highest value of no of pods/plant which reached (18.11 and 20.05) in the 1st and 2nd seasons, respectively. In this respect, Kadhim (2022) number of pods per plant is an important trait attributing to dry pod yield of faba bean production. The maximum number of pods was produced by 100 g/L. Treatment (43.57 pod plant^{-1}) as compared with the other levels especially control treatment (0 ppm SA) that gave the lowest mean of this trait (38.35 pod plant^{-1}). Rasheed Sanaa (2018) stated that treating of broad bean plant with salicylic acid (especially 100 g L^{-1}) led to significant increases in pods weight (g).

Table (5): Effect of growth regulators, concentrations and their interactions on number of pods /plant of broad bean plants (*Vicia faba* L.) in 2020/2021 and 2021/2022 seasons.

Treatments (A) / Concentration (B)	First season				Second season			
	SA	GA	NAA	Mean	SA	GA	NAA	Mean
Control	9.36	9.36	9.36	9.36	10.42	10.42	10.42	10.42
25 ppm	9.53	10.76	15.06	11.78	10.95	12.12	16.26	13.11
50 ppm	9.77	11.41	16.71	12.63	11.25	12.96	18.11	14.11
75 ppm	10.11	12.86	18.11	13.69	11.76	13.16	20.05	14.99
Mean	9.693	11.10	14.81		11.10	12.17	16.21	
L.S.D 0.05 A	0.75				0.79			
L.S.D 0.05 B	0.82				0.86			
L.S.D 0.05 AB	0.96				1.02			

3.2.2 Number of green seeds /pod

GR with their concentrations had induced significant effects on number of green seeds/pod (Table 6). GR concentrations caused a significant increase on no of green seeds/pod until to 75 ppm compared to control treatment. Obtained data in Table (6) indicated that number of green seeds/ pod was affected significantly by GR. Number of green seeds /pod under the study was significantly higher under the foliar application of NAA compared with the other GR treatments in both seasons. The number of green seeds /pod values due to foliar application of NAA recorded (5.198 and 5.378) compared to SA (4.013 and 4.186) or even GA (4.232 and 4.419) application in both seasons, respectively. Also, NAA application surpassed SA and GA by 29.52 and 28.47%, and 22.82 and 21.70% in both seasons, respectively. In this respect, Sharief and El-Hamady (2017) found that foliar application of naphthalene acetic acid up to 60 ppm exceeded of seeds number/pod, seeds number/plant, seed yield (g) /plant, 100-seed weight (g), seed yield (ton/ha) by 11.87, 23.48, 14.16, 24.91, and 26.15, respectively as the average of both seasons. It could be recommended that foliar spraying of naphthalene acetic acid up to 60 ppm improved seed yield/ha by 38.2% compared without foliar application. Rathore *et al*. (2022) indicated that spraying of NAA was found superior in terms of yield and yield attributes as well as benefit cost ratio followed by GA3 and salicylic acid. Concerning the main effect of GR-concentration (Table 6) results revealed that, number of green seeds/ pod under the study were significantly increased with increasing the concentration in both seasons. Application of NAA at a rate of 75 ppm increased number of green seeds /pod by (26.16 and 29.10%) compared to the control in both seasons, respectively. Moreover, interaction effects between GR and their concentration, indicated that spraying broad bean by NAA recorded the highest value of number of green seeds /pod which reached (5.836 and 6.054) in the 1st and 2nd seasons, respectively. Fadhil and Almasoody (2019) revealed that concentration of 300 mg L^{-1} was excelled and gave the highest average of 6.76 seeds on all the concentrations and gave the treatment of non-adding the lowest average amounted 5.67 seeds.

3.2.3 Pod weight/plant

Foliar application of NAA followed GA then SA were more effective in increasing Pod weight/plant compared with all other treatments (Table 7). Pod weight/plant values reached 472.4 and 550.4 g as results of spraying NAA, meanwhile, spraying SA recorded 222.2 and 256.1 and GA recorded 257.3 and 311.9 g in both seasons, respectively. Rathore *et al*. (2022) spraying of 40 ppm NAA exhibited the maximum fresh pod yield (105.0 q ha^{-1}) as compared to other treatments. Observed results in Table (7) revealed that, pod weight/plant was significantly increased by foliar application of NAA at a rate of 75 ppm compared with the control treatment in both seasons (Table 7). The increase percentage in pod weight/plant due to spraying with 75 ppm reached 43.38 and 63.85% compared with the control in both seasons, respectively. It is evident all tested concentration treatments were more superior compared with control. It could be suggested that improvement in pod characters was noticed by the application of mentioned effective treatment. Rasheed Sanaa (2018) found that treating of broad bean plant with salicylic acid especially (100 g L^{-1}) led to significant increases pod yield (g $plant^{-1}$). Moreover, Zidan *et al*. (2024) stated that gibberellin recorded the highest value for yield of 1076.4 g/plant compared to the control 646 g /plant.

Table (6): Effect of growth regulators, concentrations and their interactions on number of green seeds /pod of broad bean plants (*Vicia faba* L.) in 2020/2021 and 2021/2022 seasons.

Treatments (A) / Concentration (B)	First season				Second season			
	SA	GA	NAA	Mean	SA	GA	NAA	Mean
Control	3.871	3.871	3.871	3.871	3.945	3.945	3.945	3.945
25 ppm	3.954	4.112	5.412	4.493	4.124	4.357	5.625	4.711
50 ppm	4.043	4.322	5.672	4.675	4.258	4.567	5.862	4.896
75 ppm	4.194	4.621	5.836	4.884	4.417	4.488	6.054	5.093
Mean	4.013	4.232	5.198		4.186	4.419	5.378	
L.S.D 0.05 A	**				**			
L.S.D 0.05 B	0.097				0.105			
L.S.D 0.05 AB	0.116				0.124			

Table (7): Effect of growth regulators, concentrations and their interactions on pod weight /plant of broad bean plants (*Vicia faba* L.) in 2020/2021 and 2021/2022 seasons.

Treatments (A) / Concentration (B)	First season				Second season			
	SA	GA	NAA	Mean	SA	GA	NAA	Mean
Control	271.5	271.5	271.5	271.5	289.1	289.1	289.1	289.1
25 ppm	178.9	204.2	465.2	282.8	211.8	287.1	511.6	336.8
50 ppm	201.3	243.9	531.6	325.6	231.6	305.3	637.5	391.5
75 ppm	237.1	309.6	621.3	389.3	291.8	366.1	763.2	473.7
Mean	222.2	257.3	472.4		256.1	311.9	550.4	
L.S.D 0.05 A	5.67				6.03			
L.S.D 0.05 B	6.21				6.47			
L.S.D 0.05 AB	6.89				7.22			

Significant differences were found for the interaction between all GR and their concentration on Pod weight/plant in both seasons (Table 7). Spraying broad bean plants with both NAA treatments at a concentration of 75 ppm increased Pod weight/plant compared with other treatments in both seasons. Fadhil and Almasoody (2019) showed that there were significant differences for growth regulators, where the concentration 300 mg L^{-1} excelled on the all other the concentrations and gave the highest average of 3.38 and the treatment non-spraying gave the lowest average amounted 2.76 ton ha^{-1}. While the concentration of 300 mg L^{-1} gave the highest average of 291.78 g and the treatment of non-spraying gave the lowest significant difference for this trait amounted 271.11 g.

3.2.4 Number of pod /plot

Data presented in Table (8) indicated the effect of different growth regulators (GR) and their concentrations on the examined parameter of number of pod /plot, had significant effects during both growing seasons of 2020/2021 and 2021/2022. Results in Table (8) showed that significant differences in mean number of pod /plot between the three studied growths regulators (GR). Foliar application with NAA recorded the maximum mean values of number of pod /plot than both SA and GA in both seasons, respectively. Also, the increase percentages of number of pod/plot due to NAA surpassed number of pod /plot of both SA and GA in the 1st and 2nd seasons, respectively by 57.40 and 59.09%, and 38.67 and 45.99%. In this respect, Rathore *et al*. (2022) found that spraying of 40 ppm NAA exhibited the maximum number of pods/plant (87.5) as compared to other treatments.

Table (8): Effect of growth regulators, concentrations and their interactions on number of pod/plot of broad bean plants (*Vicia faba* L.) in 2020/2021 and 2021/2022 seasons.

Treatments (A) / Concentration (B)	First season				Second season			
	SA	GA	NAA	Mean	SA	GA	NAA	Mean
Control	477.9	477.9	477.9	477.9	516.4	516.4	516.4	516.4
25 ppm	476.1	531.6	756.1	587.9	511.2	547.1	844.5	634.3
50 ppm	497.1	580.1	871.1	649.4	526.1	596.2	931.6	684.6
75 ppm	516.1	643.1	991.3	716.8	576.1	661.4	1096.3	777.9
Mean	491.8	558.2	774.1		532.5	580.3	847.2	
L.S.D 0.05 A	24.03				44.24			
L.S.D 0.05 B	45.92				48.16			
L.S.D 0.05 AB	53.76				57.12			

Regarding GR concentrations (Table 8) results revealed that all GR increased No. of pod/plot with increasing the concentration of each one. The tallest broad bean plants were observed when NAA was foliar applied at 75 ppm with increasing percentages over the control treatment by 49.98 and 50.63% in the 1st and 2nd seasons, respectively. Fouda (2017) found that spraying faba bean plants with GA3 increased number of pods from 7.42 to 11.00. Huda Atab *et al*. (2023) indicated that spraying broad bean plants with salicylic acid was significantly excelled on 200 mg L^{-1} in the studied traits for the number of pods (23.01 pods $plant^{-1}$). The interaction between GR and their concentrations (Table 8) results found that maximum number of pod/plot recorded by foliar application of NAA at a concentration of 75 ppm in both seasons, respectively with values of 991.3 and 1096.3 g in the 1st and 2nd seasons, respectively. Kandil *et al*. (2011) results graphically illustrated those highest averages of number of pods /plant, resulted from sowing Giza 716 cultivars and spraying plants with 100 ppm GA3 as plant growth regulators in both seasons.

3.2.5 Pod weight (g) / plant

Data of the main values of growth regulator (GR) are presented in Table (9). Data demonstrated in Table (9) stated that main values of pod weight highly significantly affected by GR and their concentrations in both seasons. The obtained results in Table (9) showed that NAA recoded the maximum values of pod weight (31.92 and 34.81). While foliar application with SA and GA recorded the minimum values of pod weight (22.53 and 24.49) and (24.61 and 27.27) in the 1st and 2nd seasons, respectively. Also, NAA significantly increased pod weight over SA application by 41.67 and 42.13%, and over GA by 29.70 and 27.64%. Also, foliar application with NAA gave the highest pod weight compared to other GR under the study in both seasons. Rathore *et al*. (2022) spraying of 40 ppm NAA exhibited the maximum fresh pod weight (4.6 g), number of pods/plant (87.5) as well as fresh pod yield (105.0 q ha^{-1}) as compared to other treatments. Data showed (Table 9) that main values of pod weight highly significantly affected by the concentration of all GR under the study in comparison to the control treatment in both seasons. Also, pod weight significantly increased with increasing concentrations of GR. This held true in both seasons. The highest pod weight values were obtained 30.47 and 33.54 due to 75 ppm foliar application of NAA. While the minimum pod weight values were recorded 19.38 and 21.98 due to the control. Foliar application of NAA at 75 ppm significantly increased pod weight by 57.22 and 52.98% over the control treatment. Fouda (2017) found that spraying faba bean plants with GA3 increased weight of pods from 35.40 to 40.09 (g/plant).

Table (9): Effect of growth regulators, concentrations and their interactions on pod weight (g) / plant of broad bean plants (*Vicia faba* L.) in 2020/2021 and 2021/2022 seasons.

Treatments (A) / Concentration (B)	First season				Second season			
	SA	GA	NAA	Mean	SA	GA	NAA	Mean
Control	19.38	19.38	19.38	19.38	21.98	21.98	21.98	21.98
25 ppm	21.81	24.55	33.86	26.74	22.63	26.37	36.21	28.40
50 ppm	23.76	26.37	36.31	28.81	25.74	29.11	39.67	31.51
75 ppm	25.16	28.13	38.11	30.47	27.62	31.63	41.36	33.54
Mean	22.53	24.61	31.92		24.49	27.27	34.81	
L.S.D 0.05 A	1.12				1.17			
L.S.D 0.05 B	1.32				1.45			
L.S.D 0.05 AB	1.47				1.53			

Regarding the interaction between GR and their concentration, results recorded in Table (9) found that pod weight significantly affected by the second interaction (A × B) in both seasons. The maximum values of pod weight recorded 38.11 and 41.36 due to the applied 75 ppm of NAA in both seasons, respectively.

3.2.6 Pod length (cm)

Data of the main values of growth regulator (GR) are presented in Table (10). Data demonstrated in Table (10) stated that main values of pod length highly significantly affected by GR and their concentrations in both seasons. The obtained results in Table (10) showed that NAA recoded the maximum values of pod length (21.49 and 22.69). While foliar application with SA and GA recorded the minimum values of pod length (18.31 and 19.29) and (19.96 and 21.07) in the 1st and 2nd seasons, respectively. Also, NAA significantly increased pod length over SA application by 17.36 and 17.62%, and over GA by 7.66 and 7.68%. Also, foliar application with NAA gave the highest pod length compared to other GR under the study in both seasons. Rathore *et al.*

(2022) spraying of 40 ppm NAA exhibited the maximum pod width (1.3 cm), fresh pod weight (4.6 g), number of pods/plant (87.5) as well as fresh pod yield (105.0 q ha^{-1}) as compared to other treatments. Data showed (Table 10) that main values of pod length were highly significantly affected by the concentration of all GR under the study in comparison to the control treatment in both seasons. Also, pod length significantly increased with increasing concentrations of GR. This held true in both seasons. The highest pod length values were obtained 21.96 and 23.05 due to 75 ppm foliar application of NAA. While the minimum pod length values were recorded 16.14 and 17.23 due to the control. Foliar application of NAA at 75 ppm significantly increased pod length by 36.05 and 33.77% over the control treatment.

Table (10): Effect of growth regulators, concentrations and their interactions on pod length (cm) of broad bean plants (*Vicia faba* L.) in 2020/2021 and 2021/2022 seasons.

Treatments (A) / Concentration (B)	First season				Second season			
	SA	GA	NAA	Mean	SA	GA	NAA	Mean
Control	16.14	16.14	16.14	16.14	17.23	17.23	17.23	17.23
25 ppm	17.63	20.58	22.71	20.31	18.24	21.64	24.19	21.36
50 ppm	19.35	21.16	23.31	21.27	20.15	22.28	24.86	22.43
75 ppm	20.11	21.96	23.81	21.96	21,54	23.13	24.47	23.05
Mean	18.31	19.96	21.49		19.29	21.07	22.69	
L.S.D 0.05 A	0.57				0.64			
L.S.D 0.05 B	0.64				0.71			
L.S.D 0.05 AB	o.73				0.82			

Jasim and Muhsen (2014) reported that all spraying treatments led to a significant increase in pod length of mung bean plants compared to control and spraying SA with high concentration (1 mM/L) was superior compared to other spraying, which gave 7.24 compared to control. Regarding the interaction between GR and their concentration, results recorded in Table (10) found that pod length significantly affected by the second interaction (A × B) in both seasons. The maximum values of pod length recorded (23.81 and 24.47) due to the applied 75 ppm of NAA in both seasons, respectively. Fadhil and Almasoody (2019) showed a significant increase of concentrations 300 mg L^{-1} which gave the highest average amounted 18.22 cm on all concentrations.

3.2.7 Green pods weight/ plot (kg)

Data of the main values of growth regulator (GR) are presented in Table (11). Data demonstrated in Table (11) stated that main values of Green Pods weight/plot (kg) highly significantly affected by GR and their concentrations in both seasons. The obtained results in Table (11) showed that NAA recoded the maximum values of green pods weight/ plot (kg) (21.45 and 21.95). While foliar application with SA and GA recorded the minimum values of pod length (11.99 and 12.43) and (14.70 and 15.14) in the 1st and 2nd seasons, respectively. Also, NAA significantly increased green pods weight /plot (kg) over SA application by 78.89 and 76.58%, and over GA by(45.91 and 44.98%. Also, foliar application with NAA gave the highest pod length compared to other GR under the study in both seasons. Although, data showed (Table 11) that main values of green pods weight/plot (kg) were highly significantly affected by concentrations of all GR under the study in comparison to the control treatment in both seasons. Also, green pods weight/plot (kg) significantly increased with increasing concentrations of GR. This held true in both seasons. The highest green pods weight/plot (kg) values were obtained 20.28 and 20.80 due to 75 ppm foliar application of NAA. While the minimum green pods weight/plot (kg) values were recorded 9.603 and 10.12 due to the control. The growth promoter NAA enhanced the mobilization of photo assimilates in to filling seeds (El-Ghinbihi, 2007). Spraying twice of growth regulators improved the number of pods/plant, pod weigh/plant and increased seed yield by 17.7% compared without growth regulator foliar spraying (Shukla *et al*., 1997). Regarding the interaction between GR and their concentrations, results recorded in Table (11) found that green pods weight/ plot (kg) significantly affected by the second interaction (A × B) in both seasons. The maximum values of green pods weight/plot (kg) recorded 28.13 and 28.72 due to the applied 75 ppm of NAA in both seasons, respectively. Sharief and El-Hamady (2017) recommended that foliar spraying of naphthalene acetic acid up to 60 ppm and Kin of 45 ppm improved seed yield/ha by 38.2% compared without foliar application.

Table (11): Effect of growth regulators, concentrations and their interactions on green pods weight/plot (kg) of broad bean plants (*Vicia faba* L.) in 2020/2021 and 2021/2022 seasons.

Treatments (A) / Concentration (B)	First season				Second season			
	SA	GA	NAA	Mean	SA	GA	NAA	Mean
Control	9.603	9.603	9.603	9.603	10.12	10.12	10.12	10.12
25 ppm	10.63	15.53	22.75	16.30	11.09	15.91	23.17	16.72
50 ppm	12.78	15.89	25.30	17.99	13.13	16.23	25.77	18.38
75 ppm	14.96	17.76	28.13	20.28	15.37	18.31	28.72	20.80
Mean	11.99	14.70	21.45		12.43	15.14	21.95	
L.S.D 0.05 A	1.97				2.04			
L.S.D 0.05 B	2.08				2.17			
L.S.D 0.05 AB	2.17				2.26			

3.2.8 Total green pods yield (ton / feddan)

Data of the main values of growth regulator (GR) are presented in Table (12). Data demonstrated in Table (12) stated that main values of total green pods yield (ton / feddan) highly significantly affected by GR and their concentrations in both seasons. The obtained results in (Table 12) showed that NAA recoded the maximum values of Total green pods yield (ton / feddan) (8.638 and 8.830). While foliar application with SA and GA recorded the minimum values of pod length (4.855 and 5.023) and (5.938 and 6.105) in the 1st and 2nd seasons, respectively. Also, NAA significantly increased total green pods yield (ton / feddan) over SA application by 77.91 and 75.79%, and over GA by 45.46 and 44.63%. Also, foliar application with NAA gave the highest total green pods yield (ton / feddan) compared to other GR under the study in both seasons. Rathore *et al*. (2022) reported that the yield attributes like pod width, fresh pod weight, number of pods/plant as well as fresh pod yield significantly enhanced by NAA followed by gibberellic acid and salicylic acid with various concentrations, respectively. The foliar spraying of 120 ppm GA3 tended to produce plant with maximum height (116.4 cm), number of branches/plant (6.3), pod length (7.5 cm), number of seeds/pod (4.6) as well as early 50% flowering (57.3 days) whereas, spraying of 40 ppm NAA exhibited the maximum pod width (1.3 cm), fresh pod weight (4.6 g), number of pods/plant (87.5) as well as fresh pod yield (105.0 q ha^{-1}) as compared to other treatments. Data showed (Table 12) that main values of Total green pods yield (ton / feddan) highly significantly affected by the concentrations of all GR under the study in comparison to the control treatment in both seasons. Also, total green pods yield (ton / feddan) significantly increased with increasing concentrations of GR. This held true in both seasons. The highest total green pods yield (ton / feddan) values were obtained 8.11 and 8.32 due to 75 ppm foliar application of NAA. While the minimum total green pods yield (ton / feddan) values were recorded 4.08 and 4.05 due to the control. In this respect, Rasheed Sanaa (2018) treating of broad bean plant with salicylic acid especially (100 g L^{-1}) led to significant increases total yield ton $donum^{-1}$, and green seed yield (g $plant^{-1}$) and total seed yield (ton $donum^{-1}$). Moreover, Kadhim (2022) observed that 100 g/L SA significantly increased the broad bean pods yield/ha (4331.0 pods/ha) compared to the other levels of this factor. Regarding the interaction between GR and their concentration, results recorded in Table (12) found that total green pods yield (ton /feddan) significantly affected by the second interaction (A × B) in both seasons. The maximum values of total green pods yield (ton / feddan) recorded 11.25 and 11.49 due to the applied 75 ppm of NAA in both seasons, respectively. Fouda (2017) found that spraying faba bean plants with GA3 increased total yield of faba bean from 1070.28 to 1212.37 (kg/feddan). Zidan *et al*. (2024) stated that gibberellin recorded the highest value for production (3.58 kg/m^2) compared to the control (2.15 kg/m^2).

Table (12): Effect of growth regulators, concentrations and their interactions on total green pods yield (ton/feddan) of broad bean plants (*Vicia faba* L.) in 2020/2021 and 2021/2022 seasons.

Treatments (A) / Concentration (B)	First season				Second season			
	SA	GA	NAA	Mean	SA	GA	NAA	Mean
Control	4.08	4.08	4.08	4.08	4.25	4.25	4.25	4.25
25 ppm	4.25	6.21	9.10	6.52	4.44	6.36	9.27	6.69
50 ppm	5.11	6.36	10.12	7.20	5.25	6.49	10.31	7.35
75 ppm	5.98	7.10	11.25	8.11	6.15	7.32	11.49	8.32
Mean	4.855	5.938	8.638		5.023	6.105	8.830	
L.S.D 0.05 A	0.53				0.59			
L.S.D 0.05 B	0.59				0.67			
L.S.D 0.05 AB	0.67				0.74			

3.3 Chemical composition of broad bean seeds

3.3.1 Protein %

Data of the main values of growth regulator (GR) are presented in Table (13). Data demonstrated in Table (13) stated that main values of Protein % highly significantly affected by GR and their concentrations in both seasons. The obtained results in Table (13) showed that NAA recoded the maximum values of protein % (25.28 and 25.83). While foliar application with SA and GA recorded the minimum values of protein % (19.34 and 19.90) and (21.48 and 22.01) in the 1st and 2nd season, respectively. Also, NAA significantly increased protein % over SA application by 30.71 and 29.79%m and over GA by 17.69 and 17.35%. Also, foliar application with NAA gave the highest protein % compared to other GR under the study in both seasons. Jasim and Muhsen (2014) reported that all spraying treatments led to a significant increase in protein % of mung bean plants compared to control, and spraying SA with high concentration (1 mM/L) was superior compared to other spraying, which gave 22.59 % compared to control. Data showed (Table 13) that main values of protein % were highly significantly affected by the concentrations of all GR under the study in comparison to the control treatment in both seasons. Also, protein % significantly increased with increasing concentrations of GR, this held true in both seasons. The highest protein % values were obtained 24.52 and 25.02 due to 75 ppm foliar application of NAA. While the minimum protein % values were recorded 18.00 and 18.71 due to the control. Foliar application of NAA at 75 ppm significantly increased protein % by 36.22 and 33.72% over the control treatment. Kadhim (2022) showed that Salicylic acid treatment (100 g/L) significantly raised the mean of protein content of broad bean (33.6%) as compared to the other treatment levels. Regarding the interaction between GR and their concentrations, results recorded in Table (13) found that protein % significantly affected by the second interaction (A × B) in both seasons. The maximum values of protein % recorded 28.43 and 28.89 due to the applied 75 ppm of NAA in both seasons, respectively. Fouda (2017) found that spraying faba bean plants with GA3 increased protein % from 14.59 to 16.27 (%).

Table (13): Effect of growth regulators, concentrations and their interactions on protein % of broad bean plants (*Vicia faba* L.) in 2020/2021 and 2021/2022 seasons.

Treatments (A) / Concentration (B)	First season				Second season			
	SA	GA	NAA	Mean	SA	GA	NAA	Mean
Control	18.00	18.00	18.00	18.00	18.71	18.71	18.71	18.71
25 ppm	18.75	21.93	27.13	22.60	19.23	22.42	27.78	23.14
50 ppm	19.31	22.18	27.56	23.02	19.82	22.59	27.95	23.45
75 ppm	21.31	23.81	28.43	24.52	21.84	24.32	28.89	25.02
Mean	19.34	21.48	25.28		19.90	22.01	25.83	
L.S.D 0.05 A	0.37				0.48			
L.S.D 0.05 B	0.44				0.46			
L.S.D 0.05 AB	0.52				0.66			

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