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Study Of Field Performance Of Fava Bean Genetic Combinations And Their Crossbreeds Under The Influence Of Arginine Spraying

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Abstract
This study was conducted during the agricultural seasons 2022/2023 and 2023/2024 at Al -zaffarniya research station of the Department of horticulture, with the aim of estimating the genetic dimension of thirteen varieties of peas and evaluating the productive performance of their individual hybrids under the influence of spraying with arginine acid at two concentrations (0 and 250 mg L^{-1}). SSR techniques using 4 initiators and RAPD initiators (8) were used to determine genetic variability, and the analysis resulted in the selection of six varieties with the most genetically divergent and the lowest content of tannin and vicine contents. A half-crossing program was implemented to produce 15 first-generation (F_2) hybrids, and the hybrids and parents were compared in the second season according to a split-plot design within a randomized complete block design (RCBD) with three replicates.
The results revealed that parent No. 2 was superior in the number of pods (33.91 pods/plant^{-1}), while parent No. 3 recorded the highest values for pod weight (51.34 g), number of seeds per pod (9.18 seeds), weight of 100 seeds (144.86 g), and yield per plant (1659.37 g), the highest total yield of (109.90) tons ha^{-1}. At the hybrid level, the hybrid (4×1) was superior in the weight of 100 seeds (179.08 g), and the hybrid (4×3) in the number of seeds per pod (9.42 seeds), weight of 100 seeds (54.54 g), and yield per plant (1817.53 g/plant^{-1}), the highest total yield of (133.98) tons ha^{-1}. The hybrid (5×4) recorded the highest number of pods (34.80 pods /plant^{-1}). The results showed that spraying with arginine at a concentration of 250 mg L^{-1} significantly affected all studied traits except tannin. This treatment achieved the highest averages of: pod weight (42.30 g), number of pods (35.29 pods/plant^{-1}), number of seeds per pod (7.89 seeds/pod^{-1}), weight of 100 seeds (158.83 g), yield per plant (1494.33 g/plant^{-1}), and total yield (99.51) tons ha^{-1}

:Keyword *:Faba bean (Vicia faba L.), Genetic combinations, Crossbreeding, Arginine spraying,*

INTRODUCTION:

The pea plant belong that (Vicia faba L) It is characterized by being partially self-pollinated, with high external and internal hybridization rates ranging from 20% to 50%, influenced by genetic and environmental factors and the activity of pollinating insects such as honey bees (Suso and Moreno, 1999; Bishnoi et al., 2015). Peas are the fourth most important legume crops in the world after peas, chickpeas, and lentils, and its importance lies in its high protein content (20-40%), in addition to its ability to stabilize atmospheric nitrogen through its symbiotic relationship with streptococcal bacteria (Kaur et al., 2014). The crop is characterized by its ability to grow in poor soils and its tolerance to soil salinity. Its average yield is 40–45 quintals/ha, and may reach 60–75 quintals/ha under optimal conditions (Bishnoi, 2016). Broad beans are grown in India as a spring crop and consumed fresh. Due to their high productivity, they have been included in the Coordinated Research Network for Legumes (CRN) (Kumar et al., 2016; Kumar et al., 2017).

Foliar spraying is an effective method for providing nutrients to plants, especially during critical growth stages. Foliar feeding improves growth and yield and reduces the need for soil fertilizers (Singh et al., 2021; Morab et al., 2021). This method offers uniform nutrient distribution and is efficient in meeting plant requirements throughout the growth stages, although it requires periodic spraying (Gad El-Kareem, 2021; Vighnesh et al., 2021). Several studies have shown that arginine plays an important role in enhancing plant tolerance to adverse environmental conditions, such as heat, salinity, and drought. It also contributes to chlorophyll formation, increased cell division, and tissue formation (Abd-El-Monem, 2010 & Hozayn). In this context, Al-Hayani (2018) showed that spraying fava beans with concentrations of 5 and 10 mg/L of arginine led to significant increases in physiological and morphological traits,

including plant height, number of branches, stem diameter, seed weight, and protein content. Mohamed et al. (2015) also showed that spraying with arginine (200 and 300 ppm) significantly improved vegetative growth and chlorophyll content compared to gibberellic acid. The 300 ppm arginine concentration was the most effective in improving plant growth, productivity, and seed chemical composition .

MATERIALS AND METHODS

Seeds of selected broad bean varieties were sown on October 1, 2023, at the Zafaraniya Research Station, affiliated with the Horticulture Department / Spring Palm Station, to study the genetic and productive performance of genotypes under the influence of arginine spraying. A factorial experiment was conducted according to a randomized complete block design (RCBD) and a split plot design with three replicates which included two factors: the first was genetic structures, and included six parents and fifteen individual hybrids resulting from cross—taxation, and the second factor was paper spraying with arginine acid in two levels (without spraying, spraying at a concentration of 250 mg L-1). The spray coefficients were placed in the main panels, and the genetic structures in the secondary panels . Seeds were sown in lines parallel to drip irrigation pipes, with a distance of 0.75 m between lines, 1 m between replicates, and 0.2 m between plants. Each replicate contained 42 genotypes (21 genotypes × two spray treatments), resulting in a total of 126 experimental units. All agricultural maintenance operations, including irrigation, weeding, hoeing, and pest control, were carried out as needed. Based on the results of genetic fingerprinting using the SSR and RAPD techniques, six cultivars were selected from among 13 cultivars that showed clear genetic divergence.

These cultivars were Histal, Claro ED luna, Sakiz Bakala, Broad Beans, Kawadlji, and Iraqi Kurtana, and were designated (V_1–V_6), respectively. These cultivars were entered into a half-crossing program according to the first method and the fixed model of Griffing's (1956) methods, to produce first-generation hybrids (F_2). Subsequent measurements and data related to morphological, physiological, and production traits were conducted to analyze variance and estimate genetic traits.

Characteristics of the product and its components

This study included the evaluation of several traits related to yield and its components, which were measured according to the following methods.

Number of pods per plant (pod/plant^{-1}): The number of pods was counted in five randomly selected plants from each experimental unit, and the average was calculated

Average pod weight (g pod^{-1}): Green pods were collected from the same five plants used for counting and weighed to extract the average pod weight

Number of seeds per pod (seed/pod^{-1}): The seeds were counted in ten randomly selected pods from the plants, and the average was calculated

Weight of 100 seeds (g): Several samples of 100 whole seeds were taken and weighed to extract the overall average in grams

Green pod yield (g plant^{-1}): was calculated by multiplying the average number of pods by the average pod weight for each individual plant

Total yield (tons ha^{-1}): was calculated using the equation The following

The total yield of the experimental unit in hectares was calculated using the following equation: Yield of the experimental unit (g) × Area of the experimental unit (m_2) × 1000/10000

Table No. (1) shows the names and origins of the fava bean varieties

T	Item name	Origin
1	Luz DE otono	Spain
2	Histal	Spain
3	Claro ED luna	Spain
4	Local variety (Kartania(	Iraqi

5	Broad bean Quadrilogy	Netherlands
6	AGuadulce	New Zealand
7	Basic	California
8	Bakla Tohumu	Turkey
9	Bakla Sevilla	Turkey
10	Sakiz Bakala	Turkey
11	Monarch	Moroccan
12	Quads SN23	Netherlands
13	Broad Beans	America

1. Horn weight

The finding of Table (2) The presence of a significant effect of spraying with arginine acid in the average weight of the pod, as the spraying treatment with a concentration of 250 mg L^{-1} surpassed the highest weight rate of 42.30 g, compared to the comparison treatment (0 mg L^{-1}), which recorded 38.52 G. The results also revealed significant differences between the studied genotypes, which indicate a clear genetic divergence between the varieties. Father No. 3 outperformed, recording the highest average corn weight of 51.34 G, while father No. 2 recorded the lowest average of 32.03 G. This variability was reflected in the performance of the hybrids، as the hybrid (4×3) revealed the highest average pod weight of 54.54 g, while the hybrid (5×1) had the lowest weight of 26.74 g. The interaction effect between spraying and genetic makeup was also significant, as parent No. 3, when sprayed at a concentration of 250 mg/L^1, gave the highest pod weight value of 53.39 g, while parent No. 2, when sprayed at a concentration of 0, recorded the lowest value of 30.31 g. At the hybrid level, the hybrid (4×3) outperformed at the high concentration, recording 56.43 g, while the hybrid (5×1) recorded the lowest weight of 24.85 g when treated without spraying

Table influence of genetic compositions (parents and their individual hybrids) and arginine spraying on pod weight (g) of fava bean plants.

Genetic structures	Spray arginine mg^{-1} liter		Average genetic compositions
	0	250	
1	36.08 v	39.86 o	**37.97 I**
2	30.31 $\overline{b}$	z 33.76	**32.03 P**
3	49.28 f	53.39 c	**51.34 C**
4	39.71 o p	43.49 k	**41.60 H**
5	35.49 w	39.27 q	**37.38 K**
6	33.80 z	37.58 t	**35.69 N**
1*2	35.88 v	39.66o p	**37.77 J**
1*3	39.60 p	43.38 k	**41.49 H**
1*4	40.08 n	43.86 j	**41.97 G**
1*5	24.85 $\overline{d}$	28.63 $\overline{c}$	**26.74 Q**
1*6	35.92 v	39.70 o p	**37.81 J**
2*3	34.52 y	38.30 s	**36.41 M**
2*4	35.23 x	39.01 r	**37.12 L**
2*5	33.85 z	37.63 t	**35.74 N**
2*6	32.64 $\overline{a}$	36.42 u	**34.53 O**
3*4	52.65 d	56.43 a	**54.54 A**

3*5	48.82 g	52.60 d	**50.71 D**
3*6	50.84 e	54.62 b	**52.73 B**
4*5	42.52 l	46.30 h	**44.41 E**
4*6	40.85 m	44.63 i	**42.74 F**
5*6	35.93 v	39.71 o p	**37.82 J**
Arginine spray averages	**38.52 B**	**42.30 A**	

Number of pods for fava bean plants

Spraying with arginine acid at a concentration of 250 mg L^{-1} produced the highest average of 35.29 pods of $Plant^{-1}$, compared to the comparison treatment (0 mg L^{-1}), which produced 30.84 pods of $Plant^{-1}$, indicating that arginine acid spraying significantly affects the number of pods per plant, according to Table (3) results. Significant genotype differences were also found in the results, demonstrating a pronounced genetic divergence between the parents , as parent No. 2 recorded the highest number of pods, reaching 33.91 pods/$plant^{-1}$, while parent No. 1 achieved the lowest number, reaching 31.72 pods/$plant^{-1}$. This genetic variation was reflected in the performance of the hybrids, as the hybrid (5×4) outperformed, recording the highest number of pods, reaching 34.80 pods per $plant^{-1}$, while the hybrid (5×2) had the lowest, with 31.40 pods per $plant^{-1}$. The interaction between spray levels and genetic compositions was also significant, as parent No. 2 achieved the highest value at a concentration of 250 mg L^{-1}, reaching 37.40 pods per $plant^{-1}$, while parent No. 1 recorded the lowest value at a concentration of 0 mg L^{-1}, reaching 29.32 pods per $plant^{-1}$. At the hybrid level, the hybrid (5×4) showed the best response to spraying at a concentration of 250 mg L^{-1}, recording 37.30 pods per $plant^{-1}$, while the hybrid (5×2) had the lowest, with 29.00 pods per $plant^{-1}$ when no spraying was used

Table 3: Effect of genetic compositions (parents and their individual hybrids) and spraying with arginine on the number of pods (pod/plant) of fava beans

Genetic structures	Spray arginine mg^{-1} liter		Average genetic compositions
	0	250	
1	29.32 q r s	34.13 g h i	**31.72 J K**
2	32.59 j	37.40 a	**34.99 A**
3	29.30 q r s	35.11 f g	**32.20 I J**
4	30.20 op q	34.35 g- j	**32.27 I J**
5	31.51 l m n	36.32 c d e	**33.91 B C**
6	30.23 o p	35.04 f g	**32.63 F-I**
1*2	30.89 n o p	35.70 d e f	**33.29 D E**
1*3	31.09 n o	36.57 b c	**33.83 CD**
1*4	31.44 m n	35.52 de f	**33.48 CD**
1*5	29.15 r s	33.96 i j	**31.55 K**
1*6	29.99 p q r	34.80 f- i	**32.39 H I**
2*3	36.40 b c	32.55 k	**34.47 AB**
2*4	29.99 p q r	34.80 f-i	**32.39 H I**
2*5	29.00 s	33.81 j	**31.40 K**
2*6	29.99p q r	34.80 f-i	**32.39 H I**
3*4	30.83 n o p	35.64 d e f	**33.23 D E F**
3*5	30.55 o p	35.36 f	**32.95 D-G**
3*6	30.14 p q	34.95 f g h	**32.54 G H I**
4*5	32.30 k l	37.30 a b	**34.80 A**
4*6	32.10 k l m	37.49 a	**34.79 A**
5*6	30.69 n o p	35.50 e f	**33.09 D E F**
Arginine spray averages	**30.84 B**	**35.29 A**	

Number of seeds in a pod

The findings in Table (4) demonstrated that the number of seeds per pod was significantly impacted by arginine acid spraying. When arginine acid was used at a concentration of 250 mg L^{-1}, the number of seeds increased to 7.89 pod $seeds^{-1}$, as opposed to 6.84 pod $seeds^{-1}$ for the comparison treatment (0 mg L^{-1}). Additionally, the results showed a notable genetic difference between the genotypes. 9.42 pod seeds

^{1}, while the hybrid (6×2) was the least productive, with 5.51 pod seeds^{-1}. The interaction between genetic compositions and spray level also showed a significant effect,, as parent No. 3 recorded the highest average number of seeds, reaching 9.18 pod^{-1} seeds, while parent No. 6 recorded the lowest average, reaching 4.96 pod^{-1} seeds. This variation was reflected in the performance of the hybrids, as the hybrid (4×3) had the highest average number of seeds, as parent No. 3 outperformed at a concentration of 250 mg L^{-1}, recording 9.71 pod seeds^{-1}, while the lowest value was for parent No. 6 at a concentration of 0 mg L^{-1}, with 4.43 pod seeds-^{1}. In terms of hybrids, the hybrid (4×3) showed the highest number of seeds, reaching 9.95 pod seeds^{-1} when sprayed at a concentration of 250 mg/L^{-1}, while the hybrid (5×2) recorded the lowest rate, reaching 5.70 pod seeds-^{1} at a concentration of 0 mg/L^{-1}

Table 4: Effect of genetic compositions (parents and their individual hybrids) and spraying with arginine on the number of seeds in pods of fava bean plants

Genetic structures	Spray arginine mg^{-1} liter		Average genetic compositions
	0	250	
1	6.64 b	7.70 q	**7.17 L**
2	4.82 k	5.88 e	**5.35 R**
3	8.65 g	9.71 b	**9.18 B**
4	7.38 u	8.44 j	**7.91 H**
5	5.66 h	6.72 a	**6.19 P**
6	4.43 l	5.49 i	**4.96 S**
1*2	6.89 x	7.95 o	**7.42 K**
1*3	6.93 w	7.99 n	**7.46 J**
1*4	7.56 s	8.62 h	**8.09 F**
1*5	6.53 c	7.59 r	**7.06 M**
1*6	5.72 f	6.78 y	**6.25 N**
2*3	7.52 t	8.58 i	**8.05 G**
2*4	7.10 v	8.16 l	**7.63I**
2*5	5.70 g	6.76 z	**6.23 O**
2*6	4.98 j	6.04 d	**5.51 Q**
3*4	8.89 f	9.95 a	**9.42 A**
3*5	8.10 m	9.16 d	**8.63 D**
3*6	8.16 k	9.22 c	**8.69 C**
4*5	7.88 p	8.94 e	**8.41 E**
4*6	7.56 s	8.62 h	**8.09F**
5*6	6.53 c	7.59 r	**7.06 M**
Arginine spray averages	**6.84 B**	**7.89 A**	

Weight of 100 seeds

According to Table 5's results, the weight of 100 seeds was significantly affected by the application of arginine at a concentration of 250 mg L^{-1}, with an average weight of 158.83 grams as opposed to 156.57 grams at a concentration of 0 mg L^{-1}. Significant variations in genotypes with respect to this trait were also revealed by the results, indicating a definite genetic divergence between parents .Father 3 and Father 5 scored the highest weight of the 100 seeds with an average of 144.86 grams, while Father 2 was the lowest with 132.18 grams. This variation was reflected on the hybrid plants, where the hybrid (4×1) exceeded the highest weight by an average of 179.08 G, while the hybrid (6×5) was the least overweight by an average of 155.04 G. The interaction between genotypes and the level of spraying showed a significant effect, father 3 achieved the highest weight for the weight of 100 seeds when spraying at a concentration of 250 mg L^{-1} at an average of 144.96 G, while Father 2 recorded the lowest weight at a concentration of 0 mg L^{-1} at an average of 131.97 G. At the level of hybrids, the hybrid (4×1) at a concentration of 250 mg exceeded L^{-1} with a weight of 179.27 G, while the hybrid (6×5) weighed the least at a concentration of 0 mg L^{-1} with an average of 151.79 G

Table 5: Effect of genetic compositions (parents and their individual hybrids) and spraying with arginine on the weight of 100 seeds (g) of fava beans

Genetic structures	Spray arginine mg^{-1} liter	

	250	0	Average genetic compositions
1	135.88 s	132.35 t	**134.11 P**
2	132.39 t	131.97 t	**132.18 Q**
3	144.96 o	144.76 o	**144.86 M**
4	137.43 q r	136.97 r s	**137.20 O**
5	138.70 p q	138.50 p q	**144.86 M**
6	138.85 p	137.51p q r	**138.18 N**
1*2	171.25 d	171.05 d	**171.15D**
1*3	167.80 g	163.61 i	**165.70 G**
1*4	179.27 a	178.88 c	**176.08 A**
1*5	170.30 d e	167.43 g	**168.87 F E**
1*6	159.77 k	151.90 n	**155.84 L K**
2*3	178.08 a	171.21 d	**174.65 B**
2*4	171.13 d	168.26 f g	**169.70 E**
2*5	158.03 l	154.20 m	**156.11 K**
2*6	169.26 e f	168.73 f g	**168.99F-E**
3*4	171.41 d	165.88 h	**168.64 F**
3*5	158.86 k- l	158.66 k l	**158.76 J**
3*6	174.33 b	171.06 d	**172.70 C**
4*5	157.66 l	167.79 g	**162.72 H**
4*6	161.77 j	161.44 j	**161.60 I**
5*6	158.28 n	151.79 n	**155.04 L**
Arginine spray averages	**158.83 A**	**156.57 B**	

Yield of one plant

The results of Table(6) demonstrate that spraying with arginine had a significant effect on the studied trait, as the yield reached 1494.33 g plant^{-1} at a concentration of 250 mg L^{-1}, compared to 1188.14 g plant^{-1} at a concentration of 0 mg L^{-1}. The results of the same table revealed the presence of significant differences between the genotypes for this trait, reflecting a clear genetic variation among the parents. Parent 3 recorded the highest yield of 1659.37 g plant^{-1}, while Parent 2 recorded the lowest yield, recording 1125.59 g plant^{-1}. This variation was reflected in the resulting hybrid plants, as the hybrid (4×3) outperformed, achieving 1817.53 g plant-1, while the hybrid (5×1) recorded the lowest yield, with 848.58 g plant^{-1}. The interaction between genetic compositions and the level of arginine spraying showed a significant effect on the studied trait, as parent 3 recorded the highest yield at a concentration of 250 mg L^{-1}, recording 1874.86 g plant-1, while the lowest productivity was for parent 2 at a concentration of 0, reaching 988.53 g plant^{-1}. At the hybrid level, the hybrid (4×3) excelled with the highest productivity, reaching 2011.16 g plant^{-1} at a concentration of 250 mg L^{-1}, while the hybrid (5×1) was the least productive, achieving 725.08 g plant^{-1} at a concentration of 0 mg L^{-1}

Table 6: Effect of genetic compositions (parents and their individual hybrids) and spraying with arginine on the yield of one plant (g plant-1) of fava beans

Genetic structures	Spray arginine mg^{-1} liter		Average genetic compositions
	0	250	
1	1058.57 s t	1360.30 m	1209.43 J
2	988.53 u v	1262.65 o	1125.59 L
3	1443.88 j	1874.86 b c	1659.37 C
4	1198.99 p	1493.25 i	1346.12 G
5	1119.01 q	1426 17 j	1272.59 H
6	1022.48 t u	1317.67 n	1169.58 K
1*2	1109.05 q r	1415.74 j k	1262.39 H
1*3	1231.53 o p	1586.31 g	1408.92 F
1*4	1260.74 o	1558.58 g h	1409.66 F
1*5	725.08 w	972.07 v	848.58 M

1*6	1077.95 r s	1381.44 k l m	1229.69 I J
2*3	1257.28 b c d	1246.17 o	1251.73 H I
2*4	1057.26 s t	1357.42 m	1207.34 J
2*5	982.35 v	1272.13 o	1127.24 L
2*6	979.58 v	1267.27 o	1123.43 L
3*4	1623.91 f	2011.16 a	1817.53 A
3*5	1492.16 i	1860.90 c	1676.03 C
3*6	1533.03 h	1909.95 b	1720.99 B
4*5	1374.12 l m	1727.11 d	1550.62 D
4*6	1257.28 o	1673.31 e	1492.66 E
5*6	1103.41 q r	1409.58 j k l	1256.49 H
Arginine spray averages	1188.14 B	1494.33 A	

Total Yield

According to Table (7) The results of the statistical analysis, revealed that spraying fava bean plants with arginine had a significant effect on increasing production, with the highest average production reaching 99.51 tons ha^{-1} at a concentration of 250 mg L^{-1}, compared to 79.17 tons ha^{-1} ,while the treatment without spraying. The results also revealed significant genetic variation among the genotypes, with parent (3) recording the highest productivity of 109.90 tons ha^{-1}, while parent (2) achieved the lowest productivity of 75.03 tons ha^{-1}. This variation was reflected in the performance of the hybrids, as the hybrid (4×3) outperformed, recording 121.09 tons ha^{-1}, while the hybrid (5×1) was the least productive, and recording 56.55 tons ha^{-1}. The interaction between genetic compositions and arginine levels also showed a significant effect, as father (3) recorded the highest productivity at a concentration of 250 mg L^{-1}, amounting to 123.59 tons ha^{-1}, while father (2) recorded the lowest productivity when treated without spraying, amounting to 65.91 tons ha^{-1}. At the hybrid level, the hybrid (4×3) achieved the highest productivity, amounting to 133.98 tons ha^{-1} at the highest concentration, while the hybrid (5×1) recorded the lowest productivity, amounting to 48.33 tons ha^{-1} at zero concentration

Table 7: Effect of genetic compositions (parents and their individual hybrids) and spraying with arginine on the total plant yield (tons ha-1) of fava beans

Genetic structures	**Spray arginine mg^{-1} liter**		**Average genetic compositions**
	0	250	
1	70.23tu	90.68m	**80.46K**
2	65.91vw	84.15op	**75.03M**
3	96.21j	123.59c	**109.90D**
4	79.90q	99.51i	**89.71H**
5	74.58r	94.96j	**84.77I**
6	68.15uv	87.74n	**77.94L**
1*2	73.92rs	94.44jk	**84.18I**
1*3	82.09pq	105.73g	**93.91G**
1*4	84.04op	103.87gh	**93.95G**
1*5	48.33x	64.77w	**56.55N**
1*6	71.84st	92.09klm	**81.97JK**
2*3	83.79op	83.02op	**83.41I J**
2*4	70.46tu	90.45m	**80.46K**
2*5	65.49w	84.75o	**75.12M**
2*6	65.26w	84.41op	**74.83M**
3*4	108.21f	133.98a	**121.09A**
3*5	99.44i	123.94c	**111.69C**
3*6	102.16h	127.20b	**114.68B**
4*5	91.61lm	115.08d	**103.34E**
4*6	87.46n	111.51e	**99.48F**
5*6	73.56rs	93.92jkl	**83.74I**
Arginine spray	79.17B	99.51A	

averages			

RESULTS AND DISCUSSION

The finding in Tables (2, 3, 4, 5, 6, and 7) revealed significant differences between the studied genotypes, which can be attributed to the variation in the genetic content carried by the parents and their hybrids. This genetic variation reflects the diversity of genotypes and their different performances. It is a crucial indicator that can be used as a basic input for quantitative genetic analysis of traits, estimating the components of genetic variance and the nature of the genetic action controlling them. These genetic differences are necessary for identifying the most superior genotypes, which contributes to improving breeding programs for leguminous plants. The results also demonstrate that spraying with arginine acid had a clear significant effect on all yield traits, in addition to a significant effect of the interaction between genotypes and spray levels. Foliar spraying with arginine acid led to a significant improvement in the number of pods per plant, the number of seeds per pod, seed weight, and yield per plant, which positively impacted the total yield. This improvement is attributed to several physiological and biochemical mechanisms contributed to by arginine, a nitrogen-rich amino acid that is an important source of regulatory compounds within plant cells. The most prominent of these mechanisms include: stimulating root nodules in leguminous plants by enhancing symbiotic interactions with Rhizobium bacteria, which increases the efficiency of atmospheric nitrogen fixation, an essential element in the synthesis of proteins and enzymes associated with flower and seed formation (El-Sayed et al., 2021); contributing to the synthesis of polyamines such as spermidine and spermine, compounds that play an important role in cell division and differentiation, especially in reproductive tissues (Gupta et al., 2018); and stimulating the production of plant hormones such as gibberellins, auxins, and cytokinins, which regulate flower development, fruit set, and seed filling (Wang et al., 2019).

Enhancing chlorophyll biosynthesis and improving the uptake of important nutrients such as phosphorus, potassium, and magnesium, which increases photosynthetic efficiency and carbohydrate levels need for grain formation. Production of nitric oxide (NO), a signaling molecule that contributes to regulating pod and seed growth by reducing oxidative stress and stimulating cell expansion. The integration of these mechanisms reflects the vital role arginine plays in enhancing the physiological performance of leguminous plants and improving their quantitative yield. These results are consistent with previous studies such as Tian et al. (2020) and Sheyaa & Kisko (2023), which confirmed the effectiveness of arginine in supporting reproductive growth and improving yield by regulating physiological processes and providing nutrients.

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