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Original Research Article

Evaluation of Growth Traits Performance and Genetic Parameters for Various Genotypes of Faba Bean (*Vicia faba* L.) Under the Effect of Potassium Foliar

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Abstract: This study evaluated the performance and genetic parameters of faba bean genotypes under potassium foliar application. We used a split-plot design within an R.C.B.D., incorporating three potassium levels (0, 100, and 150 kg.ha) and six genotypes. PO6-O13FB/FL outperformed others in key traits, including plant height (137.62 cm) and dry weight (44.38 g/plant). Potassium at 150 kg/ha^{-1} significantly enhanced all traits, with the highest interaction values for branches per plant (19.33) and plant height (143.36 cm). High heritability and genetic gains suggest potential for improving faba bean productivity. The genotype PO6-O13FB/FL outperformed others in most traits, including plant height (137.62 cm), leaf area (1659.21 cm²/plant), and dry weight (44.38 g/plant). Potassium foliar application at 150 kg ha^{-1} significantly improved all studied traits, with the highest values for branches per plant (19.33) and plant height (143.36 cm). The study found that phenotypic variances were more significant than genetic and environmental variances, with leaf area showing the highest increase. All traits exhibited broad-sense heritability, with leaf area having the highest genetic gains. Moderate genetic gains were noted for other traits at various potassium concentrations.

Keywords: Genotypes, Potassium, Genetic Parameters, *Faba Bean*.

INTRODUCTION

Faba bean (*Vicia faba*), a member of the legume family (Fabaceae), is an annual plant primarily cultivated in temperate regions. It is one of the oldest crops cultivated by humans, dating back thousands of years in the Mediterranean and the Middle East (Choi *et al*., 2024). Faba bean is valued for its high nutritional content and diverse applications in human and animal nutrition (Merhij and Al-Khafaji, 2023). Beyond its nutritional benefits, faba bean is an economically significant crop in animal feed and food industries. However, it can pose health challenges for individuals with glucose-6-phosphate dehydrogenase (G6PD) deficiency, leading to favism, a genetic disorder causing sensitivity to Vicine, a compound in fava beans (Corzo-Ríos *et al*., 2022). Global faba bean production has grown remarkably, driven by increasing demand for plant-based proteins and sustainable agriculture. According to an IMARC (2023) report, the global faba bean market is expected to grow at a compound annual growth rate (CAGR) of 4% from 2024 to 2029. In 2022, the global market volume was approximately 8.6 million tons, projected to reach 11.0 million tons by 2028, with a CAGR of 4.11% from 2023–2028. In Iraq, faba bean cultivation covered an area of 1661.6 kg/donum, producing 28,181 thousand tons (Iraqi Central Statistical Organization, 2023).

Faba bean cultivation faces challenges, including competition with other winter crops like wheat and alfalfa, marketing issues, and insufficient financial incentives for farmers (Chaurasia *et al*., 2022), improving agricultural practices, and providing farmer support. Evaluating faba bean genotypes is a crucial step toward enhancing crop productivity and efficiency across different environments (Huthily *et al*., 2020) and tolerance to environmental stresses. Genotypic

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evaluations rely on precise analytical methods, such as field experiments and genetic, phenotypic, and environmental variance analyses. These studies identify genotypes best suited to local conditions, aiding crop productivity (Alatawi *et al*., 2024). Understanding genetic relationships among genotypes allows for new varieties combining high-yield and superior-quality traits (Deb and Paul, 2024).

Studying genetic parameters in faba beans is essential to understanding the genetic traits responsible for productivity, quality, and environmental tolerance (Hasan and Abdullah, 2020). Additionally, examining genetic parameters, such as heritability, expected genetic gain, and genetic variance, clarifies how traits are inherited and the influence of additive and non-additive genetic factors in improving desirable traits (Al-Zubaidi and Al-Jubouri, 2016). These studies address food security challenges by developing genotypes adapted to diverse environmental conditions, supporting sustainable agriculture, and advancing agricultural development goals (Hasan *et al*., 2022). Potassium is a significant nutrient essential for the growth and development of plants, including faba beans. It regulates key physiological processes, such as photosynthesis, carbohydrate transport, and enzyme activation (Ahmed *et al*., 2023). Potassium also improves plants' ability to absorb water and nutrients, enhancing resilience to adverse environmental conditions such as drought and salinity. Foliar potassium application effectively improves crop productivity and quality (Fouda *et al*., 2022). The study aimed to evaluate the performance of six genotypes for growth traits in *Faba bean* (*Vicia faba*), and genetic parameters, including phenotypic, genetic, and environmental variances, heritability, and expected genetic gain, and the effects of different potassium concentrations on the growth traits of fava beans.

MATERIALS AND METHODS

The experiment was conducted in a farmer's field within the Kirkuk Irrigation Project area during the 2024–2025 growing season. The soil was prepared using a chisel plough with two perpendicular passes, followed by levelling and smoothing. Triple superphosphate (P_2O_5) was applied at a rate of 200 $kg\cdot ha^{-1}$ as a phosphorus source during planting. Nitrogen fertilizer was provided as urea (46% nitrogen) at a 200 $kg\cdot ha^{-1}$ rate, split into two applications: the first during planting and the second one month later (Sabahi *et al*., 1992).

Experimental Factors

1. Potassium Foliar Application:
2. Foliar application of potassium sulfate (K_2O, 52%) was applied at the 7–8 leaf stage at three concentrations: 0, 100, and 150 $kg\cdot ha^{-1}$, referred to as K_0, K_1, and K_2, respectively.
3. Genetic Variants:
4. Six genetic variants of faba bean (Vicia faba L.) were evaluated:PO6-OO2FB/FL, PO6-OO3FB/FL, PO6-OO5FB/FL, PO6-O11FB/FL, PO6-O13FB/FL and PO6-O14FB/FL

The experiment was conducted using a split-plot design within a completely randomized block design (R.C.B.D) with three replications. Each replication contained three main plots, each receiving one of the potassium treatments. Thus, each replication included 18 experimental units, with the treatments assigned randomly in the factorial combination between the two study factors. Each main plot was divided into six subplots, with broad bean cultivars assigned randomly. Each experimental unit contained four rows, each 3 meters long, with 0.75-meter spacing between rows and 20 cm between plants. A 1-meter gap was left between each experimental unit, and the distance between lines was 0.70 meters with 0.25-meter spacing between holes. A 1-meter gap was also maintained between each main plot and between blocks.

Two to three seeds were planted in each hole, and after one week of germination, the plants were thinned to one plant per hole. The following traits were studied: the number of pods per plant, the number of seeds per pod, the 100-seed weight (g), seed yield (kg/ha), biological yield (kg/ha), and harvest index (%).

1. Genetic Statistical Analysis: The experiment's results were statistically analyzed using a completely randomized block design (R.C.B.D) with a split-plot arrangement. Means were compared using Duncan's multiple range test with the assistance of the SAS and Genes software programs (Al-Zubaidi and Al-Jubouri, 2016). The following genetic parameters were estimated:
2. Phenotypic, Genetic, and Environmental Variance: Variances of the three types (phenotypic, genetic, and environmental) were estimated using the method described by Walter (1975) for each potassium level, as follows: $^2\sigma_E + {}^2\sigma_G = \sigma_P{}^2$ ، $\sigma_E{}^2 = \frac{Mse}{r}$ ، $\frac{\mathbf{Msg-Mse}}{\mathbf{r}} = \sigma_G{}^2$
3. Broad-Sense Heritability: Heritability in the broad sense (H²) was calculated using the method of Hanson *et al*. (1956) and was interpreted according to the ranges provided by Ali (1999) and Mohammed (2000), where heritability below 40% is low, between 40-60% is moderate, and above 60% is high, as follows:

$$H^2{}_{B.S} = \frac{\sigma_G{}^2}{\sigma_P{}^2}$$

4. Expected Genetic Gain: Expected genetic gain (G.A) was estimated based on the expected improvement limits. If the gain is less than 10, it is considered low; between 10 and 30, it is considered moderate; and above 30 is considered high, according to Agarwal and Ahmed (1982). The formula used is:

$G.A = K. \times H^2_{B.\,s.} \times \sigma P$

where:

- G.A = Expected genetic gain
- K = Constant (1.40) at 20% selection intensity
- H^2_B.S = Broad-sense heritability
- σP = Phenotypic standard deviation of the trait.

RESULTS AND DISCUSSION

Evaluation of Genetic Variants, Potassium Spraying, and Their Interactions on the Studied Traits

The results of the variance analysis, as shown in Table 1, indicate that the mean squares for potassium spraying, genetic variants, and their interaction were statistically significant at the 1% probability level for all the studied traits, except for the number of branches per plant, which was significant at the 5% probability level. However, the interaction between genetic variants and potassium spraying for traits such as days to 50% flowering, number of leaves per plant, leaf area (cm²/plant), and dry weight (g/plant) did not reach statistical significance. The significant differences observed among the genetic variants of faba bean (Vicia faba L.) reflect the diversity in their genetic makeup. These differences underscore the ability of various genetic variants to express their productive potential under the same environmental conditions (Mageed and Ali, 2024). Regarding potassium spraying, its significant effect highlights the importance of potassium as an environmental factor capable of inducing substantial changes in plants' physiological and productive traits (Al-Fartossi and Abd-elWahed, 2023). This interaction reflects the mutual influence of genetic and environmental factors in determining the studied traits (Younis *et al.*, 2022).

The results showing significant differences in these factors affirm the importance of carefully selecting suitable genetic variants and relying on well-designed fertilization programs to improve productivity and quality in faba bean crops. They also highlight the significance of the interaction between genetic and environmental factors in achieving sustainable production (Aleuzayr and Abdulqader, 2024; Humada *et al.*,2024; Humada *et al.*,2025).

Table 1: Analysis of Variance for the Studied Traits

Source of Variation	**d.f**	**Mean Squares**		
		Days to 50% Flowering	**Branches/Plant**	**Leaves/Plant**
Replications	2	1027.62	193.00	3095.17
Potassium	2	1293.35**	279.96**	2239.04**
A Error	4	221.96	38.61	125.06
Genetic Variants	5	327.98**	46.27**	383.63**
Potassium × Variants	10	12.48n.s	4.10*	14.44n.s
B Error	30	11.11	1.67	21.08

Source of Variation	**d.f**	**Plant Height (cm)**	**Leaf Area (cm²/Plant)**	**Dry Weight (g/Plant)**
Replications	2	3276.95	319161.63	3634.58
Potassium	2	995.65**	161826.71**	2205.81**
A Error	4	116.07	1789.94	232.75
Genetic Variants	5	836.75**	152515.53**	376.66**
Potassium × Variants	10	48.70**	1931.72n.s	11.80n.s
B Error	30	17.12	1562.38	18.59

- Significance Levels:
  - (**) Significant at 1% probability level.
  - (*) Significant at 5% probability level.
  - (n.s) Not significant.

Days to 50% Flowering (Days)

The results presented in Table (2) indicate that the genetic variants showed significant differences in the number of days to 50% flowering. The genetic variant (PO6-O13FB / FL) was the earliest to reach 50% flowering, requiring only 65.33 days, while the genetic variant (PO6-OO3FB / FL) recorded the latest flowering, taking 84.33 days. The superiority of specific genetic variants in reaching 50% flowering can be attributed to genetic differences between these variants (Hasan *et al.*,2023). Conversely, late-flowering variants benefit from a more extended growth period to develop higher productivity traits, such as increased vegetative biomass or enhanced pod size. The performance of these late-flowering variants also depends on their efficient utilization of natural resources, with genetic factors enhancing the regulation of physiological processes such as photosynthesis and energy metabolism, ultimately influencing flowering timing (Shiferaw and Tarekegne, 2024).

The same table also shows that spraying with potassium concentrations significantly affected the days to 50% flowering. The application of 150 kg.L-1 potassium resulted in the earliest flowering (66.50 days), whereas the absence of spraying (0 kg.L-1) led to the latest flowering (83.44 days). The reduction in the time required to reach 50% flowering with 150 kg.L-1 potassium can be explained by potassium's vital role in enhancing physiological processes in plants (Al-Badrawi *et al*., 2022). The same table data reveal no significant differences in the interaction between genetic variants and potassium spraying concentrations regarding the number of days to 50% flowering.

Table 2: Mean Effects of Genetic Variants, Potassium Spraying, and Their Interaction on the Number of Days to 50% Flowering

Genetic Variants	**0 kg.ha⁻¹**	**100 kg.ha⁻¹**	**150 kg.ha⁻¹**	**Mean Effect of Genetic Variants**
PO6-OO2FB / FL	b84.33	d75.33	gh62.33	b74.00
PO6-OO3FB / FL	a91.33	b84.33	cd77.33	a84.33
PO6-OO5FB / FL	bc83.00	cd77.00	fg66.66	b75.55
PO6-O11FB / FL	bc83.00	de74.33	fg65.66	b74.33
PO6-O13FB / FL	d75.33	gh62.66	h58.00	c65.33
PO6-O14FB / FL	b83.66	de73.33	ef69.00	b75.33
Mean Effect of Potassium	a83.44	ab74.50	b66.50	

Branches per Plant

The results presented in Table (3) indicate that the genetic makeup significantly affected the trait of branches per plant. It is noteworthy that the genetic composition (PO6-O13FB / FL) showed superiority, recording the highest number of branches at (14.22), while the lowest number of branches was observed in the genetic composition (PO6-OO3FB / FL), which averaged (7.12) branches. The superiority of the genetic composition (PO6-O13FB / FL) in the number of branches can be attributed to its genetic characteristics, which directly control the expression of branching traits (Ali and Kumar, 2005), and the results align with Pandit *et al*., (2020).

The same table also reveals that potassium spray concentrations significantly affected the trait of branches per plant. The potassium spray concentration of (150) kg/hectare showed the highest number of branches at (14.68), while the lowest number of branches was recorded in the no-spray treatment (0) kg/hectare, with (7.01) branches. Potassium is an essential nutrient that plays a pivotal role in regulating physiological processes in plants. When applied at the appropriate concentration (150) kg/hectare, potassium enhances cell division and meristematic tissue growth, improving branch formation in fava bean plants. Potassium also improves photosynthesis efficiency by regulating stomata's opening and closing, which increases carbohydrate flow to developing tissues, including branch formation areas (Zahoor, 2017).

Data from the same table indicates that interactions significantly affected the traits of branches per plant. The interaction between the genetic composition (PO6-O13FB / FL) and the potassium spray concentration (150) kg/hectare resulted in the highest number of branches, reaching (19.33) branches. In contrast, the lowest number was recorded in the interaction between the genetic composition (PO6-OO3FB / FL) and the no-spray potassium concentration (0) kg/hectare, with (5.00) branches. The superiority of the interaction between the distinguished genetic composition (PO6-O13FB / FL) and the potassium spray concentration (150) kg/hectare in the number of branches can be attributed to a combination of genetic and environmental factors (Kumar *et al*., 2020). These results agree with those of Faris and Mohammed (2020).

Table 3: Average Effect of Genetic Compositions, Potassium Spraying, and Their Interactions on the Trait of Branches per Plant

Genetic Composition	**0 kg/hectare**	**100 kg/hectare**	**150 kg/hectare**	**Average Effect of Genetic Compositions**
PO6-OO2FB / FL	ef 6.33	cd 8.96	b 14.73	b 10.01
PO6-OO3FB / FL	f 5.00	def 7.36	cd 9.00	c 7.12
PO6-OO5FB / FL	ef 6.13	cd 8.96	b 14.70	b 9.93
PO6-O11FB / FL	cde 7.63	cde 8.50	b 15.00	b 10.37
PO6-O13FB / FL	c 10.00	b 13.33	a 19.33	a 14.22
PO6-O14FB / FL	def 7.00	cde 8.33	b 15.33	b 10.22
Average Effect of Potassium	b 7.01	ab 9.24	a 14.68	

Number of Leaves per Plant

The results in Table (4) show significant differences in the mean values of genetic compositions for the number of leaves per plant trait. The genetic composition (PO6-O13FB / FL) showed the highest number of leaves, reaching (47.72) leaves per plant, while the genetic composition (PO6-OO3FB / FL) had the lowest average, with (27.27) leaves per plant. The superior performance of the genetic composition (PO6-O13FB / FL) in terms of the number of leaves in faba bean is attributed to its combination of genes that enhance meristematic activity and contribute to increased rates of cell division in plant tissues. This genetic composition exhibits exceptional adaptability to diverse environmental conditions, which promotes overall plant growth and increases leaf density (Marschner, 2012). Physiologically, this genetic composition has higher efficiency in nutrient absorption and distribution, particularly potassium, which plays a vital role in regulating osmotic pressure (Hasan *et al*., 2024), enhancing photosynthesis, stimulating nutrient transport within the plant, and increasing the number of leaves (Taiz and Zeiger, 2006). These results are consistent with those of Shferaw and Tarekegne (2024).

The same table shows that the application of potassium spray concentrations significantly affected the number of leaves per plant. The potassium spray concentration of (150) kg/hectare resulted in the highest number of leaves, which was (49.41) leaves per plant, while the lowest number of leaves was recorded in the non-spray treatment (0) kg/hectare, with (27.10) leaves per plant. The superior performance of the potassium spray concentration of (150) kg/hectare in increasing the number of leaves in faba bean is attributed to the essential role of potassium in enhancing the plant's physiological processes (Hasanuzzaman *et al*., 2018). Furthermore, the data from the same table show no significant differences in the interaction effect between the genetic compositions and potassium spray concentrations on the number of leaves per plant.

Table 4: Average Effect of Genetic Compositions, Potassium Spraying, and Their Interactions on the Trait of Number of Leaves per Plant

Genetic Composition	0 kg/hectare	100 kg/hectare	150 kg/hectare	Average Effect of Genetic Compositions
PO6-OO2FB / FL	e 28.60	cd 40.76	b 49.56	b 39.64
PO6-OO3FB / FL	f 18.96	ef 24.93	d 37.93	c 27.27
PO6-OO5FB / FL	ef 24.16	d 39.23	b 50.06	b 37.82
PO6-O11FB / FL	e 27.56	cd 40.16	b 49.86	b 39.20
PO6-O13FB / FL	d 37.66	bcd 44.83	a 60.66	a 47.72
PO6-O14FB / FL	ef 25.66	cd 40.46	bc 48.36	b 38.16
Average Effect of Potassium	c 27.10	b 38.40	a 49.41	

Plant Height (CM)

The results presented in Table (5) indicate significant differences in the average genetic compositions for the trait of plant height (cm). It is observed that the genetic composition (PO6-O13FB / FL) recorded the highest plant height, reaching 137.62 cm, while the lowest plant height was recorded for the genetic composition (PO6-OO3FB / FL), which was 107.83 cm. This superiority is attributed to the unique genetic characteristics of this genotype, which promote vertical plant growth (Kumar and Singh, 2018), and the results agree with Shferaw and Tarekegne (2024).

The table also shows that potassium spraying concentrations significantly affected plant height (cm). The highest plant height (133.21 cm) was recorded with the potassium spraying concentration of 150 kg/hectare, while the lowest plant height (118.42 cm) was recorded in the no-spray treatment (0 kg/hectare). The increase in plant height in broad beans with a potassium concentration of 150 kg/hectare can be explained by potassium's vital role in enhancing the plant's physiological processes (Ali and Farooq, 2019).

The data from the table also shows that interactions significantly affected plant height (cm). The interaction between the genetic composition (PO6-O13FB / FL) and the 30 kg/hectare potassium spraying concentration resulted in the highest plant height, reaching 143.36 cm. On the other hand, the lowest plant height was recorded with the interaction of the genetic composition (PO6-OO3FB / FL) and the no-spray treatment (0 kg/hectare), which was 94.16 cm. The superiority of the genetic composition (PO6-O13FB / FL) with the potassium spraying treatment at 30 kg/hectare for plant height is due to the positive interaction between genetic and environmental factors (Ali and Farooq, 2019). The results are in agreement with Bedada *et al*. (2024).

Table 5: Average Effect of Genetic Compositions, Potassium Spraying, and Their Interactions on Plant Height (cm)

Genetic Compositions	0 kg/hectare	100 kg/hectare	150 kg/hectare	Average Effect of Genetic Compositions
PO6-OO2FB / FL	def 121.16	cd 124.43	b 134.60	b 126.73
PO6-OO3FB / FL	g 94.16	ef 115.03	f 114.30	c 107.83
PO6-OO5FB / FL	de 122.53	de 122.20	b 135.30	b 126.67
PO6-O11FB / FL	def 121.20	d 123.06	ab 136.66	b 126.97
PO6-O13FB / FL	bc 131.26	ab 138.23	a 143.36	a 137.62
PO6-O14FB / FL	def 120.20	d 123.93	b 135.06	b 126.40
Average Effect of Potassium	b 118.42	ab 124.48	a 133.21	

Leaf Area (cm²/Plant)

The results presented in Table (6) indicate significant differences in the averages of genetic compositions for the leaf area (cm²/plant) trait. The genetic composition PO6-O13FB / FL showed the highest leaf area, recording 1659.21 cm²/plant, while the lowest leaf area was observed in PO6-OO3FB / FL, with an average of 1247.80 cm²/plant. The superior performance of PO6-O13FB / FL in leaf area is attributed to a combination of genetic factors that positively influence leaf growth and development. Leaf area is a critical indicator of a plant's ability to perform photosynthesis effectively and has a high potential to increase the number and size of leaf cells (Table 4) (Taiz and Zeiger, 2006). The results align with the findings of Alatawi *et al*., (2024).

The same table shows that potassium spraying concentrations significantly affected the leaf area (cm²/plant) trait. The potassium concentration of 150 kg/hectare showed the highest leaf area, recording 1549.16 cm²/plant, while the lowest leaf area was observed under the non-spraying treatment (0 kg/hectare), with a value of 1359.88 cm²/plant. Potassium is an essential nutrient that plays a pivotal role in numerous physiological processes in plants. It significantly affects their growth and development (Abdullah and Hasan, 2020), contributing to increased leaf size and leaf area. Secondly, potassium strengthens the cell walls and increases the flexibility of plant cells, enabling the leaves to expand and grow in area. This enhances the plant's ability to form healthy plant tissues, which increases leaf area. Thirdly, potassium significantly improves the plant's nutritional balance, particularly concerning nitrogen and phosphorus levels. This balance promotes leaf growth, which results in an increased leaf area that effectively contributes to improved plant productivity (El-Shaboury, 2024).

The data in the table also note that no significant differences were observed in the interaction effect between genetic compositions and potassium spraying concentrations on leaf area (cm²/plant).

Table 6: Mean Effect of Genetic Compositions, Potassium Spraying, and Their Interactions on Leaf Area (cm²/Plant)

Genetic Compositions	0 kg/hectare	100 kg/hectare	150 kg/hectare	Mean Effect of Genetic Compositions
PO6-OO2FB / FL	e1358.93	cd1468.90	c1541.20	b1456.34
PO6-OO3FB / FL	g1148.30	f1234.87	e1360.23	c1247.80
PO6-OO5FB / FL	e1382.67	d1462.40	c1542.43	b1462.50
PO6-O11FB / FL	e1378.17	cd1476.40	cd1517.27	b1457.28
PO6-O13FB / FL	cd1527.80	b1656.80	a1793.03	a1659.21
PO6-O14FB / FL	e1363.40	cd1488.20	c1540.77	b1464.12
Mean Effect of Potassium	c1359.88	b1464.59	a1549.16	

Dry Weight (g/Plant)

According to Table (7) data, significant differences were observed in the average dry weight (g/plant) across the genetic compositions. The genetic composition PO6-O13FB / FL showed the highest dry weight, reaching 44.38 g/plant, while the lowest dry weight was recorded for the genetic composition PO6-OO3FB / FL, which was 23.94 g/plant. Dry weight is an important indicator that reflects the plant's efficiency in converting nutrients into plant tissues, as it depends on its ability to utilize resources such as water and nutrients. In the case of faba bean, genetic traits play a significant role in determining this attribute. The superiority of the genetic composition in terms of dry weight is due to several genetic and physiological factors. Firstly, the genetic composition is the primary factor influencing the plant's ability to exploit nutrients and water efficiently. The plant's genetic makeup can enhance the cells' ability to grow and proliferate (Tables 4, 5, and 6), which increases the volume of dry tissues (Alatawi *et al*., 2024).

From the same table, it can be observed that spraying with potassium concentrations significantly affected the dry weight (g/plant) trait. The highest dry weight was recorded at (45.52 g/plant) with a potassium concentration of (150 kg/hectare), while the lowest dry weight was recorded at (23.41 g/plant) with no potassium spraying (0 kg/hectare). This can be explained by the role of potassium in improving various physiological processes in plants (Hafez *et al*., 2019).

The data in the same table also show that no significant differences were found in the interaction between genetic compositions and potassium spraying concentrations for dry weight (g/plant).

Table 7: Average Effect of Genetic Compositions, Potassium Spraying, and Their Interactions on Dry Weight (g/Plant)

Genetic Compositions	Zero (kg/hectare)	100 kg/hectare	150 kg/hectare	Average Effect of Genetic Compositions
PO6-OO2FB / FL	fg 22.50	cd 34.10	b 46.23	b 34.27
PO6-OO3FB / FL	g 15.63	ef 24.93	de 31.26	c 23.94
PO6-OO5FB / FL	fg 22.63	d 32.56	b 46.73	b 33.97
PO6-O11FB / FL	fg 23.06	d 33.50	b 46.53	b 34.36
PO6-O13FB / FL	cd 34.33	bc 41.50	b 57.33	a 44.38
PO6-O14FB / FL	fg 22.33	cd 33.80	b 45.03	b 33.72
Average Effect of Potassium	b 23.41	ab 33.40	a 45.52	

The Phenotypic, Genetic, and Environmental Variances

The phenotypic, genetic, and environmental variances in the faba bean (Vicia faba L.) reflect the complexity of the factors that influence its growth and productivity. Phenotypic variances refer to observable differences in traits such as plant height, number of leaves, and pod count, which result from the interaction between genetic composition and environmental factors. Genetic variances reflect the differences in the genetic material of plants, which is the driving force behind breeding programs (Hasan and Abdullah, 2021). These genetic variances allow the selection of the best-performing genetic compositions under different environmental conditions (Fageria, 2007).

The results from Table (8) show the values of phenotypic, genetic, and environmental variances for the studied traits under three potassium spray concentrations (0, 100, and 150 kg/ha), denoted as (0 K, K1, and K2). Phenotypic variance outperformed genetic variance, and both exceeded environmental variance. Phenotypic variance ranged across the three concentrations, with the highest recorded for leaf area at a concentration of (0) kg/ha, 16246.41, and the lowest recorded for branch number at a concentration of (100) kg/ha, 2.79. Regarding genetic variance, it ranged across the three concentrations, with the highest recorded for leaf area at a concentration of (150) kg/ha, which was 16109.48, and the lowest recorded for seed number per pod at a concentration of (0) kg/ha, which was 1.27. Meanwhile, the environmental variance was lower and ranged across the three concentrations, with the highest recorded for leaf area at a concentration of (150) kg/ha, which was 1051.18, and the lowest recorded for dry weight at a concentration of (100) kg/ha, which was 0.45. In general, the variance values showed differences based on the potassium spray concentrations, which provides evidence of the importance of studying the interactions (phenotypic × genetic × environmental). The higher values of genetic variance allow plant breeders to select and improve the studied traits.

The Broad Sense Heritability

The broad sense heritability in faba bean (Vicia faba L.) refers to the transfer of genetic traits from one generation to the next through genes and the mechanisms that control gene expression. Additive genetic heritability occurs when different genes independently affect a particular trait (Chaurasia *et al.*, 2202), while dominance heritability involves the effects arising from interactions between dominant and recessive genes. In faba bean, broad sense heritability relies on the analysis of genetic variance, which includes components of additive variance (attributed to variance between different alleles) and dominance variance (attributed to interactions between dominant and recessive genes) (Altaweel and Al-Shakarchy, 2021). Broad sense heritability is important in breeding programs because it helps determine the optimal method for selecting genetic compositions that exhibit desirable traits such as disease resistance, tolerance to harsh environmental conditions, and increased productivity (Al-Zubaidi and Al-Jubouri, 2016).

Based on the ranges provided by Ali (1999) and Mohammed (2000), heritability values are classified as low (<40%), moderate (40-60%), and high (>60%). According to the data presented in Table (8), the broad sense heritability values were high for all the studied traits under three potassium concentrations: (0, 100, and 150 kg/ha), denoted as (0K, K1, and K2). The high broad sense heritability values for the mentioned traits are attributed to the high genetic variance compared to environmental variance, as seen in the same Table (8).

Genetic Improvement

Genetic improvement in the faba bean (Vicia faba L.) represents one of the key tools for increasing productivity, improving disease and pest resistance, and enhancing its nutritional quality (Chaurasia *et al.*, 2202). Genetic improvement in fava beans is achieved through various techniques, such as selective hybridization, genetic modification techniques, and genetic inheritance, to improve targeted traits (Hasan and Abdullah, 2020).

Genetic improvement in faba bean depends on a deep understanding of the genetic structure of different seed varieties, where genetic variance between individuals is assessed, and individuals carrying genetic mutations with positive effects on targeted traits are selected (Hasan and Abdullah, 2021). The expected genetic improvement includes enhancing the bean's ability to adapt to the environment, increasing productivity through higher flower numbers, successful pollination, increased seed size, and improved seed quality (Sarker and Islam, 2018).

The expected genetic improvement can be expressed as a percentage, according to Johanson *et al*., (1955) and Kempthorne (1969), based on the ranges proposed by Robinson *et al*., (1951) and Agarwal and Ahmed (1982). These ranges classify the expected genetic improvement as low (<10%), moderate (10-30%), and high (>30%). According to the data in Table (8), the expected genetic improvement percentages for the studied traits under three potassium concentrations (0, 100, and 150 kg/ha), denoted as (0K, K1, and K2), were high for leaf area traits. Moderate expected improvement was observed for the number of days to 50% flowering at a concentration of 0 kg/ha, the number of leaves per plant at 0 and 100 kg/ha, plant height (cm) at 0 and 150 kg/ha, and dry weight (g/plant) at 0 and 100 kg/ha. However, the expected genetic improvement was low for the remaining traits at their respective concentrations.

Concluded that the expected genetic improvement response (i.e., selection response) varied from high to low across all traits, indicating the importance of selection to improve these traits (Hasan and Abdullah, 2020). Research focusing on genetic improvement in faba bean relies on techniques such as genetic mutations, molecular genetics studies, and assessing relationships between individuals to identify the best genetic sources for targeted traits. In the future, the focus is expected to be on improving the plants' ability to adapt to climate changes, which requires improving resistance to environmental stresses and tolerance to high temperatures and drought (Merhij *et al*., 2024).

Table 8: Genetic Parameters for the Studied Traits

Trait	K	Phenotypic Variance	Genetic Variance	Environmental Variance	Broad-Sense Heritability	Expected Genetic Gain
Days to 50% Flowering	K0	198.00	195.33	2.67	0.99	19.43
	K1	43.41	36.50	6.91	0.84	7.76
	K2	33.59	32.18	1.41	0.96	7.77
Number of Branches (Plant)	K0	35.48	35.06	0.42	0.99	8.24
	K1	17.22	16.68	0.54	0.97	5.63
	K2	2.79	1.27	1.52	0.45	1.06
Number of Leaves (Leaf/Plant)	K0	177.00	167.77	9.24	0.95	17.65
	K1	162.02	161.51	0.51	1.00	17.76
	K2	53.98	46.36	7.62	0.86	8.83
Plant Height (cm)	K0	73.07	71.80	1.26	0.98	11.76
	K1	71.14	45.86	25.28	0.64	7.61
	K2	112.36	80.80	31.55	0.72	10.67
Leaf Area (cm^2/Plant)	K0	16246.41	16109.48	136.93	0.99	176.94
	K1	14987.93	14982.93	5.00	1.00	171.34
	K2	8711.33	7660.15	1051.18	0.88	114.90
Dry Weight (g/Plant)	K0	201.65	200.95	0.69	1.00	19.81
	K1	180.97	180.53	0.45	1.00	18.79
	K2	29.60	25.33	4.27	0.86	6.52

CONCLUSIONS

The study concluded that genotype PO6-O13FB/FL performed best across most traits, including plant height, leaf area, and dry weight. Potassium foliar application at 150 kg.ha^{-1} significantly improved all traits, particularly for plant height and branches per plant. Phenotypic variances were higher than genetic and environmental variances, with the highest values for leaf area. High broad-sense heritability was observed for all traits, indicating strong genetic influence. The study showed high genetic gains for leaf area and moderate gains for traits like plant height and dry weight with different potassium levels.

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