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EFFECT OF POTASSIUM FERTILIZER ON SPRING SUNFLOWER GENOTYPES IN IRAQ

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ABSTRACT
With the aim of studying different levels of potassium fertilizer and its effect on the performance of different varieties of sunflower crops, estimating heritability at all levels of fertilizer, and determining which variety gives a higher yield, a field experiment was carried out in a private field outside the university for the spring season of 2025. The land was prepared for cultivation at the experiment site by plowing, smoothing and leveling according to recommendations. An RCBD design was used with three replicates, according to the split-plot arrangement, fertilization levels (0.0-, 0.1-, 0.2-, and 0.3-ton K ha^{-1}) were distributed on the main plots, and the varieties (Aqmar, Local, Ishaqi1, Ishaqi2, and Tarazan) were distributed on the secondary plots. The results showed that the fertilizer level exceeded 0.1 ton K ha^{-1} with the highest yield per individual plant reaching 109.14 g due to its superiority in the highest plant height (221.87 cm) with the highest number of leaves (31.20 leaf $plant^{-1}$), the highest leaf area index (5.537), the highest disc weight (188.22 g), the lowest number of days to reach physiological maturity (94.00 day), the highest crop growth rate (4.447 g plant day^{-1}). The Tarazan variety excelled with the highest individual plant yield of 95.08 g due to it having a high number of green leaves (29.00 leaf $plant^{-1}$) and a high leaf area index (4.930). It also had the highest disc weight (127.65 g) and the highest crop growth rate (4.172 g plant day^{-1}). The standard error values and coefficient of variation were low for the traits studied and at the four fertilization levels, the genetic variation was greater than the environmental variation for most of the traits studied, the percentage of heritability in the broad sense was very high for all the traits studied at the potassium fertilization level of 0.0 ton K ha^{-1}, ranging between 91.9% and 99.0% for the two traits of individual plant yield and the number of days to physiological maturity. Heritability was high for all traits at the level of 0.1 ton Kha^{-1}, ranging between 68.7% and 98.9% for the two traits of the number of days of physiological maturity and leaf area index, while the heritability in the broad sense was high for most traits at the fertilization level of 0.2 ton Kha-1, ranging between 86.4% and 99.5% for the weight of 500 seeds and number of days to physiological maturity, and the heritability was high for most traits at the high level of fertilizer (0.3 ton K ha^{-1}), ranging between 73.9% and 99.8% for the two traits, number of days to physiological maturity and crop growth rate, the heritability was medium for the trait of plant height reached 55.2%.

INTRODUCTION
The sunflower (*Helianthus annuus* L.) is a strategic oil crop that occupies an advanced position in global agricultural production, as it is distinguished by its ability to grow in diverse environmental conditions and by its high content of oil with high nutritional and industrial value **(Ashraf & Siddiqi, 2024)**. Sunflower oil is widely used in human nutrition and food industries due to its high levels of unsaturated fatty acids, especially linoleic and oleic acids, as well as its content of natural antioxidants, which give the oil high stability against oxidation and improve its storage quality. (**Kumar & Verma, 2019**) The crop is also an important source of vegetable proteins and animal fodder, as its waste after pressing the seeds represents food, it is rich for animals because of the proteins, fibers and minerals it contains, which enhances its multiple economic value (**Such et al., 2024**). The importance of its cultivation in Iraq lies in the possibility of exploiting the appropriate climatic conditions during the spring and spring seasons to increase local production of vegetable oils and reduce dependence on imports, in addition to its role in diversifying agricultural cycles and improving soil fertility (**Hladni et al., 2023**).
Fertilization is one of the basic factors affecting sunflower productivity and the quality of its crop, as the plant's efficiency in growth and production depends on the availability of major nutrients, especially potassium, which contributes to regulating many physiological processes within plant **(Tiwari and Singh, 2022)** Potassium represents one of the vital elements responsible for regulating the water balance within plant cells by controlling the opening and closing of stomata, in addition to activating the enzymes responsible for the process of photosynthesis and the formation of carbohydrates and transporting them from the leaves to the productive parts. Understanding the vital role of potassium in the growth and productivity of sunflower is an essential step towards improving its nutritional management and achieving high productivity and outstanding oil quality under the environmental conditions of Iraq. Providing sufficient and balanced potassium fertilization not only enhances the physiological performance of the plant, but also contributes to the long-term sustainability of production of this important crop **(Kumar & Verma, 2019)**.
Potassium also works to enhance the plants' resistance to various environmental stresses such as drought, salinity, and high temperatures, as it helps increase the efficiency of water absorption and improve the ionic balance within

the cells, which leads to the plant remaining in a stable physiological state under non-optimal conditions for growth **(Tiwari & Singh, 2022),** Many studies indicate that supplying plants with sufficient quantities of potassium fertilizer leads to improved growth of the shoot and root systems and increases the area of the leaves and their chlorophyll content, which reflects positively on the efficiency of the photosynthesis process and increases the overall production of the plant, as potassium plays an important role in activating many enzymes and regulating the transfer of carbohydrates within the plant, which leads to improved growth and productivity in oil crops, including sunflower **(Hawkesford et al., 2023)**. When using 4 levels of potassium fertilizer (0, 50, 100, and 150 kg K ha^{-1}), **Ahmed et al. (2021)** indicated that the sunflower crop responded to the levels of potassium fertilization, and the results showed that increasing the level of potassium fertilization led to an increase in seed yield, as the yield reached 2617 kg ha^{-1} at the level of 150 kg K ha-^{1} this confirms the importance of potassium fertilization in improving the productivity and quality of the sunflower crop.
Varieties are considered one of the important factors influencing the productivity of the sunflower crop, as they differ among themselves depending on their genetic composition and their ability to adapt to environmental conditions, which is reflected in the growth traits and components of the yield. Many studies have shown that there are significant differences between the varieties in seed yield, as **Kaya et al. (2023)** mentioned when they studied three varieties of sunflower, Bosfora, P64LE119, and LG5582, that the variety LG5582 was significantly superior in seed yield compared to the other two varieties, as the seed yield reached 4191 kg ha^{-1} due to its superiority in some yield components such as the weight of 1000 seeds and the number of seeds per disk, which led to an increase in the overall productivity of the plant.

MATERIALS AND METHODS

In order to study different levels of potassium fertilizer and its effect on the performance of different varieties of sunflower crops, estimate heritability at all levels of fertilizer, and determine which variety gives a higher yield, a field experiment was carried out in a private field outside the university for the spring season of 2025. The land was prepared for cultivation at the experiment site by plowing, smoothing and leveling according to recommendations. An RCBD design was used with three replicates, according to the arrangement of the split plots, fertilization levels (0.0, 0.1, 0.2, and 0.3 tons K ha^{-1}) were distributed on the main plots, and the varieties (Aqmar, Local, Ishaqi1, Ishaqi2, and Tarazan) were distributed on the secondary plots. the distance between one line and another was 75 cm and between one plant and another 25 cm. Planting was done by placing 2-3 seeds in the hole, thinned to one plant after the plants reached the stage of two leaves, they were fertilized with potassium sulfate fertilizer (41.5% K) according to the levels mentioned for the experiment in one batch before planting, and nitrogen fertilizer 350 kg N ha^{-1} in the form of urea (46% N) was added in three batches, the first two weeks after germination, the second in the elongation stage, and the third at the beginning of the flowering stage. The crop management operations were carried out, such as irrigation, manual weeding, and the rest field operations whenever necessary, five intermediate plants were taken for each experimental unit, which were selected randomly. The traits of plant height (cm), number of leaves, leaf area index, disc weight, weight of 500 seeds, number of days to physiological maturity, crop growth rate, and plant yield were measured.

Statistical analysis:

The data of the studied traits were statistically analyzed using the Excel and Genestat programs according to the analysis of variance (ANOVA) in the split-plot arrangement, and significance was tested with the F test at the level significance 0.05, the arithmetic means were compared using the least significant difference (LSD) with a significance level 0.05 for all means according to what was stated by **Steel and Torrie (1981)**.

Estimation of some statistical criteria and genetic parameters.

The coefficient of variation (C.V.%) was calculated to estimate the homogeneity between the samples, and the standard error (SE) was estimated to estimate the homogeneity between trait data for all levels of fertilization. Genetic, environmental and phenotypic variation and heritability in the broad sense were estimated for each fertilizer level using the genetic analysis program SPAR. 2.0 According to **Singh and Chaudhary (2010)**, genetic, environmental, and phenotypic variances were calculated as follows

$\sigma^2 G = (MSg-MSe)/r$

$\sigma^2 E = MSe$

$\sigma^2 P = \sigma^2 G \ \sigma^2 E$,

where:

MSg: the mean square of the genotypes

MSe: the mean square of the experimental error

r: the number of replicates

$\sigma^2 G$, $\sigma^2 E$, and $\sigma^2 P$ = genetic, environmental, and phenotypic variances respectively.

The genetic variation coefficient (GCV) and the phenotypic coefficient of variation (PCV) were also estimated as follows:

$GCV\% = \sqrt{(\sigma^2 g)}/\bar{x}\,100$

$PCV\% = \sqrt{(\sigma^2 p)}/\bar{x}\,100$

The degree of heritability in the broad sense, h^2b.s, was also calculated according to the following equation:

$h^2.b.s = \sigma^{\wedge 2}\ g / \sigma^{\wedge 2}\ p \times 100$.
If the heritability is less than 40%, it is considered low, 40-60% is considered moderate, and more than 60% is considered high heritability **(Al-Authari 1982)**.

RESULTS AND DISCUSSION

Plant Height (cm)

The results of Table (1) indicate that there are highly significant differences between the levels of potassium fertilizer and the varieties and the interaction between them in the trait of plant height. It is clear from the table that potassium fertilization at different levels worked to reduce plant height, as this trait was significantly affected by the difference in the level of potassium fertilization. The plants of the control treatment (0.0 ton K ha^{-1}) had the highest plant height with a mean of 222.13 cm, and the plants of the first level (0.1 ton K ha^{-1}) did not differ significantly from them with a mean of 221.87 cm, followed by the second fertilizer level (0.2 ton K ha^{-1}) with a mean of 215.80 cm, while the lowest plant height was at the last potassium fertilizer level (0.3 ton K ha^{-1}) with a mean of 211.33 cm. The reason for the low height of the plants that received potassium may be due to the fact that potassium accelerated the plants' arrival to the reproductive phase and stopped the increase in height was observed with the appearance of flower inflorescences, compared to plants that did not receive potassium, whose vegetative growth continued and their height increased. This result is consistent with what was found by (**Cheng, 2024**)
the varieties that differed significantly among themselves in the trait of plant height. The Aqmar variety excelled with the highest mean plant height of 226.25 cm, and the Ishaqi2 variety did not differ significantly from it with a mean of 224.42 cm. This also did not It differed significantly from the Ishaqi1 variety with a mean of 221.75 cm, and the Tarazan variety did not differ significantly from it with a mean of 219.33 cm. As for the lowest mean plant height, it was for the local variety, which reached 197.17 cm. This is because the plant height trait is highly variable between varieties and varies according to the genotypes due to the genetic nature of the variety. This result agreed with **Fadel and et al. (2014)** who found Significant differences between the varieties in plant height, the Flami variety excelled in giving the highest plant height.
Table (1) also shows that the varieties responded significantly to the levels of fertilization. The direction of the response was fluctuating, in general, potassium fertilization caused a decrease in plant height with an increase in the amount of potassium fertilizer. The highest plant height was for the interaction between the Ishaqi2 variety and the control treatment with a mean of 248.00 cm, while the lowest height of the plant reached 190.00 cm, for the same interaction with a decrease of 58.00 cm.

Table 1. Plant height (cm) of sunflower varieties as affected by potassium levels (Spring 2025).

varieties	levels of potassium fertilizer (ton K ha^{-1})				
	0.0	0.1	0.2	0.3	Mean
Aqmar	224.00	231.00	215.00	235.00	226.25
Local	195.67	184.00	209.00	200.00	197.17
Ishaqi1	224.00	214.00	220.33	228.67	221.75
Ishaqi2	248.00	234.33	225.33	190.00	224.42
Tarazan	219.00	246.00	209.33	203.00	219.33
L.S.D.	6.41				3.21
Mean	222.13	221.87	215.80	211.33	
L.S.D.	5.18				

Number of green leaves (plant $leaf^{-1}$).

The results of Table 2 indicate that there are highly significant differences between the levels of potassium fertilizer and the varieties and the interaction between them in the number of effective leaves. The fertilizer level exceeded 0.1 ton K ha^{-1} with a mean number of leaves of 31.20 leaf $plant^{-1}$, followed by the fertilizer level of 0.2 ton K ha^{-1} with a mean number of leaves of 1 plant. 29.00 leaf $plant^{-1}$, followed by the control treatment with a mean of 27.87 leaf $plant^{-1}$. As for the plants of the high level of potassium fertilizer (0.3 ton K ha^{-1}), they gave the lowest mean number of leaves, amounting to 24.87 leaf $plant^{-1}$. The increase in the number of leaves of the first level of potassium fertilizer (0.1 ton K ha^{-1}) is due to the fact that this level's plants had a high plant height (Table 1), thus increasing the number of internodes and then increasing the number of leaves. This is consistent with what **Choudhary (2024)** found, who indicated that moderate potassium fertilization improves vegetative growth and increases the number of leaves and other growth factors by improving the balance of nutrients and physiological processes in the plant.
The varieties differed significantly in the trait of effective leaves, as the variety Ishaqi2 excelled with the highest number of leaves, reaching 29.67 leaf $plant^{-1}$, the varieties Aqmar and Tarazan did not differ significantly from it, with means reaching 29.25 and 29.00 leaf $plant^{-1}$, while the lowest number of effective leaves was for the local variety, amounting to 25.08 leaf $plant^{-1}$. The reason for the superiority of the variety Ishaqi 2 is due to its possession of the higher plant height means more petioles and therefore more leaves (Table 1). Also, the difference

in the number of leaves between varieties is often due to great genetic diversity between varieties, this is consistent with what was found **Todesco et al., (2023)**.
Table (2) also shows that the varieties responded in a highly significant way to the fertilization levels. The response was mostly towards an increase in the number of leaves when potassium fertilizer was added, to the level of 0.2 ton K ha^{-1}, while the number of leaves decreased at the fertilizer level of 0.3 ton K ha^{-1} compared to the 0.0 ton K ha^{-1} treatment, the highest number of leaves was for the interaction treatment between the Tarazan variety and the fertilizer treatment 0.1 ton K ha^{-1} with a mean of 32.00 leaf plant^{-1}, the two interaction treatments of the same variety in the control treatment and the Ishaqi2 variety at the low fertilizer level did not differ significantly with a mean of 31.00 leaf plant^{-1} for both, while the lowest mean number of leaves was 22.33 leaf plant^{-1} for the interaction treatment between the local variety and the high fertilizer treatment (0.3 ton K ha^{-1}).

Table 2. Number of leaves (plant leaf^{-1}) of sunflower varieties as affected by potassium levels (Spring 2025).

varieties	levels of potassium fertilizer (ton K ha^{-1})				
	0.0	0.1	0.2	0.3	Mean
Aqmar	29.00	36.00	27.00	25.00	29.25
Local	23.00	26.00	29.00	22.33	25.08
Ishaqi1	27.00	30.67	30.00	25.00	28.17
Ishaqi2	29.33	31.33	30.00	28.00	29.67
Tarazan	31.00	32.00	29.00	24.00	29.00
L.S.D.	1.81				0.91
Mean	27.87	31.20	29.00	24.87	
L.S.D.	0.71				

Leaf area index (%)
The results of Table 3 indicate that there are highly significant differences between the levels of potassium fertilizer and the varieties and the interaction between them in the leaf area index trait. It is clear from the table that potassium fertilization at different levels worked to increase the leaf area index, as this trait was significantly affected by the difference in the level of potassium fertilizer. The 0.1 ton K ha^{-1} fertilizer treatment had the highest leaf area index of 5.537%, followed by the 0.2 ton K ha^{-1} fertilizer treatment. mean 4.997%, while the lowest mean for the leaf area index in the control treatment (0.0 ton K ha^{-1}) was 3.898%. The significant increase in leaf area index (LAI) when adding potassium fertilizer reflects the effective role of potassium in supporting leaf growth. Potassium enhances photosynthesis by regulating the opening of stomata and activating enzymes. It also supports the transfer of carbon metabolites to different parts of the plant, allowing the formation of more expanded leaves. This explains the superiority of the 0.1 ton K ha^{-1} treatment, which produced the highest LAI, followed by 0.2 ton K ha^{-1}. this is consistent with what was found by **(Xu, 2020) and Sardans and Penuelas, (2021)**, who indicated that potassium plays a major role in regulating stomatal opening, improving photosynthesis efficiency, and increasing leaf expansion, which is reflected in an increase in leaf area index.
The table also shows that the varieties responded highly significantly to the leaf area index trait, the variety Ishaqi1 excelled with the highest mean index of 5.023%, the varieties Ishaqi2 and Tarazan did not differ significantly from it with a mean leaf area index of 4.975 and 4.930 for each of them, respectively. As for the lowest mean of the leaf area index, it was for the local variety, which amounted to 4.322, the Aqmar variety did not differ significantly from with a mean of 4.410. The reason for the variation of the varieties in the leaf area index is due to the genetic nature of the variety, which makes the leaves more effective in using light or distributing organisms. Also, genetic variation may affect how the variety responds to environmental factors such as water, light, and nutrients, then the leaf area and its index (LAI) differs according to the varieties. This result confirms what **Hassan(2016)** found, as they showed the different varieties of sunflowers differ significantly in LAI.
Table (3) also shows that the varieties responded significantly to the levels of fertilization. The response was towards increasing the leaf area when potassium fertilizer was added compared to the control treatment (without potassium fertilization). In general, the highest means for the leaf area index were at the fertilizer level of 0.1 ton K ha^{-1}, then it tended to decrease when the fertilizer level was increased, reaching the level of 0.3 ton K ha^{-1}. The highest means for the leaf area index 6.320 % for the interaction between the variety Tarazan and the fertilizer treatment of 0.1 ton K ha^{-1}, while the lowest mean for the leaf area index was 3.143% for the interaction between the variety Aqmar and the control treatment.

Table 3. Leaf area index(%) of sunflower varieties as affected by potassium levels (Spring 2025).

varieties	levels of potassium fertilizer (ton K ha^{-1})				
	0.0	0.1	0.2	0.3	Mean
Aqmar	3.143	5.577	4.823	4.097	4.410
Local	4.323	3.840	5.230	3.893	4.322
Ishaqi1	4.603	5.790	5.263	4.437	5.023

Ishaqi2	**4.263**	**6.160**	**4.317**	**5.160**	**4.975**
Tarazan	**3.157**	**6.320**	**5.350**	**4.893**	**4.930**
L.S.D.	**0.850**				**0.425**
Mean	**3.898**	**5.537**	**4.997**	**4.496**	
L.S.D.	**0.540**				

Disc weight (g)

The results of Table 4 indicate that there are highly significant differences between the levels of potassium fertilizer and the varieties and the interaction between them in the trait of the Disc weight. The table shows that there are significant differences between the levels of potassium fertilizer, the low fertilizer level 0.1 ton K ha^{-1} exceeds with a mean disc weight of 188.22 g, followed by the medium fertilizer level (0.2 ton K ha^{-1}) with a mean disc weight of 162.01 g. As for the lowest mean disc weight, it was 138.73 g for plants with a high level of potassium fertilizer (0.3 ton K ha^{-1}), the control treatment did not differ from it with a mean disc weight of 140.42 g. The reason for the superiority of the fertilizer level of 0.1 ton K ha^{-1} is due to its superiority in having a high plant height, as well as its superiority in having the highest number of leaves and the highest leaf area index (Tables 1, 2, and 3). In a study on sunflowers, **Al Doori and Al Delymi (2014)** indicated that adding potassium at a moderate level led to a significant increase in head diameter, number of seeds, weight of 1000 seeds, and total yield compared to not adding potassium,

The varieties differed significantly among themselves in disc weight, the Tarazan variety had the highest mean disc weight of 172.65 gm, followed by the Ishaqi1, Ishaqi2 and Qamar varieties with mean disc weight of 163.52, 160.90 and 147.66 g, for the three varieties respectively, while the lowest disc weight was for the local variety with a mean of 142.00 g. This is due to differ in disc weight due to the genetic nature of the variety. The reason for the superiority of the Tarazan variety is also due to its having a high number of leaves as well as a high leaf area index (Tables 2 and 3). This result is consistent with what was found by **Todesco et al., (2021)** and **Du et al., (2023)**.

Table (4) also shows that the varieties responded in a highly significant way to the fertilization levels. The response was mostly towards an increase in the weight of the disc when potassium fertilizer was added, to the level of 0.2 ton K ha^{-1}, while the weight of the disc decreased at the fertilizer level of 0.3 ton K ha^{-1} compared to the 0.0 ton K ha^{-1} treatment for most varieties, the highest disc weight was for the interaction treatment between the Tarazan variety and the 0.2 ton K ha^{-1}fertilizer treatment with a mean of 188.33 g, followed by the interference of the same variety when treating 0.1 ton K ha^{-1} with a mean of 182.01 g, while the lowest mean disc weight was for the interaction between the local variety and control treatment with a mean of 118.67 g.

Table 4. Disc weight (g) of sunflower varieties as affected by potassium levels (Spring 2025).

varieties	**levels of potassium fertilizer (ton K ha^{-1})**				
	0.0	**0.1**	**0.2**	**0.3**	**Mean**
Aqmar	**140.43**	**178.42**	**134.96**	**136.81**	**147.66**
Local	**118.67**	**174.21**	**151.64**	**123.47**	**142.00**
Ishaqi1	**145.97**	**213.11**	**164.06**	**130.92**	**163.52**
Ishaqi2	**126.05**	**193.33**	**171.06**	**153.17**	**160.90**
Tarazan	**170.96**	**182.01**	**188.33**	**149.29**	**172.65**
L.S.D.	**3.02**				**1.51**
Mean	**140.42**	**188.22**	**162.01**	**138.73**	
L.S.D.	**2.10**				

Weight of 500 seeds (g)

The results of Table 5 indicate that there are significant differences between the levels of potassium fertilizer and the highly significant ones for the varieties and the interaction between them and the levels of fertilization in terms of the weight of 500 seeds. The table shows that there are significant differences between the levels of potassium fertilizer, as the high fertilizer level (0.3 ton K ha^{-1}) exceeded it with a mean seed weight of 32.76 g, the medium fertilizer level did not differ significantly from it. (0.2 ton K ha^{-1}) with a mean seed weight of 31.58 g. The lowest mean seed weight was 30.33 g for the control treatment (0.0 ton K ha^{-1}). This difference is attributed to the fact that potassium enhances the transport of sugars and nutrients, from the leaves to the seeds during the seed filling stage, it supports the growth of cells inside them, which increases the accumulation of carbohydrates, proteins and fats, thus increasing the final weight of the seeds, this is consistent with what was found by **Hasan et al., (2022**) and **Çakmak, (2020**) where they found that high potassium fertilization improves seed weight by enhancing the transfer of metabolites and nutrients to the seeds during the growth stage.

The varieties differed significantly in trait of 500 seed weight, the Ishaqi2 variety had the highest mean weight of 500 seeds, reaching 36.00 g, followed by the local and Aqmar varieties, which did not differ significantly from each other, with means of 31.80 and 30.64 g, while the lowest mean weight of 500 seeds was for the Tarazan variety, with a mean of 29.06 g. This difference is mainly due to the genetic variation between the varieties, and

the reason for the Ishaqi2 variety being superior with the highest seed weight is due to its having a high plant height and leaf area index (Table 1 and 3). It also excelled with the highest number of leaves (Table 2), which helped it to have a high disc weight (Table 4), which resulted in the superiority with the highest seed weight. This result confirms with what was found by **Arslan and Diler (2024)**, where a significant difference was observed between the varieties in the production traits related to the seed weight, the SUN 2259 CL variety recorded the highest 1000 seed weight compared to the other varieties.
Table (5) also shows that the varieties responded highly significantly to the fertilization levels. The response was mostly towards an increase in the weight of 500 seeds when potassium fertilizer was added, the highest weight was at the level of 0.3 ton K ha^{-1}, while it began to decrease at the level of fertilizer 0.2, then the level of 0.1, followed by the 0.0 ton K ha^{-1} treatment for most of the varieties. The highest weight of 500 seeds was for the interaction between the Aqmar variety and the fertilizer treatment of 0.3 ton K ha^{-1}, with a mean of 39.06 g, the two interaction treatments did not differ from it between the Tarazan variety at the same fertilizer treatment and the Ishaqi2 variety when the fertilizer treatment was 0.1 ton K ha^{-1}, while the lowest mean weight of 500 seeds was for the interaction treatment between the Ishaqi1 variety and the fertilizer treatment Ishaqi1 variety and the fertilizer treatment 0.3 ton K ha^{-1}, with a mean of 25.77 g.

Table 5. Weight of 500 seeds (g) of sunflower varieties as affected by potassium levels (Spring 2025).

varieties	levels of potassium fertilizer (ton K ha^{-1})				
	0.0	0.1	0.2	0.3	Mean
Aqmar	26.11	26.16	31.24	39.06	30.64
Local	28.92	34.50	37.13	26.66	31.80
Ishaqi1	33.64	32.95	27.64	25.77	30.00
Ishaqi2	36.59	38.17	35.04	34.20	36.00
Tarazan	26.41	24.87	26.85	38.10	29.06
L.S.D.	2.55				1.28
Mean	30.33	31.33	31.58	32.76	
L.S.D.	1.39				

Number of days to 75% physiological maturity (day)

The results of Table 6 indicate that there are highly significant differences between the levels of potassium fertilizer and the varieties and the interaction between them in the trait of days to maturity(DTM). The table shows that potassium fertilization had an effective effect in reducing the number of days to physiological maturity. The plants of the three fertilizer levels (0.1, 0.2 and 0.3 ton K ha^{-1}) were earlier in reaching physiological maturity with the lowest number of days amounting to 94.00, 94.07 and 94.60 days, respectively, without any significant difference between them. As for the plants of the control treatment (0.0 ton K ha^{-1}), their plants were late in reaching 75% physiological maturity with the highest number of days amounting to 95.67 days. The reason for the earliness of the plants that obtained Potassium in reaching physiological maturity may be due to the fact that potassium accelerated the plants' arrival to the reproductive phase with the appearance of flower inflorescences, compared to plants that did not receive potassium, which continued their vegetative ripening, thus delaying their arrival to physiological maturity, thus reducing the time period required to reach 75% of physiological maturity. These results are consistent with studies that showed that adequate addition of potassium reduces the growth period before maturity in oil crops such as sunflower as **Çakmak (2020)** indicated in his study on the role of potassium in improving physiological performance and increasing the speed of maturity in oil plants.
The varieties differed significantly in reaching 75% physiological maturity. The Ishaqi2 variety was superior in its early plants by reaching 75% physiological maturity with the fewest number of days of 93.83 day. The Ishaqi1 variety did not differ significantly from it by the number of days of 94.33 day. While the Tarazan variety was late in its plants reaching 75% physiological maturity with the highest mean number of days with a mean 95.42 day. The reason for the Ishaqi2 variety being early is due to the fewest days to reach physiological maturity, because it has a high plant height and leaf area index (Tables 1 and 3), it also had the highest number of leaves and the highest seed weight (Tables 2 and 5), which helped it to have a high disc weight (Table 4), which resulted in earlier physiological maturity. This result is consistent with **Ada (2023)**. He was found that the different varieties of sunflower differed significantly in the number of days until physiological maturity, as the P63MM54 variety was the fastest in reaching physiological maturity, while the Tunca variety was the most delayed.

Table 6. Number of days to 75% physiological maturity (day) of sunflower varieties as affected by potassium levels (Spring 2025).

varieties	levels of potassium fertilizer (ton K ha^{-1})				
	0.0	0.1	0.2	0.3	Mean
Aqmar	94.00	94.00	94.00	97.00	94.75
Local	96.67	92.00	95.33	95.00	94.75
Ishaqi1	96.00	93.00	94.00	94.33	94.33

Ishaqi2	**95.67**	**93.00**	**93.00**	**93.67**	**93.83**
Tarazan	**96.00**	**98.00**	**94.00**	**93.00**	**95.42**
L.S.D.	**1.49**				**0.75**
Mean	**95.67**	**94.00**	**94.07**	**94.60**	
L.S.D.	**0.98**				

Crop growth rate (gm plant day^{-1})

The results of Table 7 indicate that there are highly significant differences between the levels of potassium fertilizer and the varieties and the interaction between them in trait of the crop growth rate. The table shows that there is a significant difference between the levels of potassium fertilizer, as the low fertilizer level (0.1 ton K ha^{-1}) exceeded the highest mean growth rate of 4.447 g plant day^{-1}, followed by the medium fertilizer level (0.2 ton K ha^{-1}) with a mean crop growth rate of 4,120 g plant day^{-1}, while the lowest crop growth rate (CGR) was for the high level of potassium fertilizer treatment (0.3 ton K ha^{-1}) with a mean of 3,087 g plant day^{-1}, due to the reason for its superiority, the fertilizer level of 0.1 ton K ha^{-1} in terms of crop growth rate (CGR) led to its superiority in most growth traits, it had the highest plant height (221.87 cm), the highest number of leaves (31.20 leaf plant^{-1}) and the highest leaf area index (5.537%), which helped it excel with the highest disc weight (188.22 g), accompanied by the lowest number of days to physiological maturity. (94.00 day) (Tables 1, 2, 3, 4 and 6) These results are consistent with what **Zaki et al. (2023)** found that applying appropriate levels of potassium enhances the overall growth of the plant and increases the mass of leaves, stems and roots. It has been noted that sometimes lower levels may give a higher growth rate compared to higher levels due to improving the balance between vegetative growth and early maturity.

The table also shows that the varieties differed significantly in trait of crop growth rate, the Tarazan variety excelled with the highest mean crop growth rate of 4.172 g plant day^{-1}, followed by the Ishaqi2, Ishaqi1 and Aqmar varieties with means of 3.918, 3.727 and 3.616 g plant day^{-1}, while the lowest crop growth rate was for the local variety with a mean of 3.055 g plant day^{-1}. The reason for the Tarazan variety's superiority in the crop growth rate (CGR) trait is due to its superiority with the highest disc weight of 172.65 g (Table 4). This result is consistent with what **Hassan (2016)** found in a study on sunflower, where a significant difference was observed between the varieties in the crop growth rate (CGR) trait.

Table (7) also shows that the varieties responded significantly to fertilization levels. The response was mostly towards increasing the growth rate of the crop when potassium fertilizer was added. The highest growth rate was at the level of 0.1 ton K ha^{-1}, began to decrease at the level of 0.2 ton K ha^{-1} fertilizer., followed by the 0.0 ton K ha^{-1} treatment, then the 0.3 ton K ha^{-1} level with the lowest crop growth rates. The highest growth rate was for the interaction between the Ishaqi1 variety and the 0.1 ton K ha^{-1} fertilizer treatment with a mean of 5.163 g plant day^{-1}, while the lowest mean crop growth rate was 2.230 g plant day^{-1} for the interaction treatment between the local variety and the fertilizer treatment of 0.3 ton K ha^{-1}.

Table 7. Crop growth rate (gm plant day^{-1}) of sunflower varieties as affected by potassium levels (Spring 2025).

varieties	**levels of potassium fertilizer (ton K ha^{-1})**				
	0.0	**0.1**	**0.2**	**0.3**	**Mean**
Aqmar	**3.735**	**4.094**	**3.997**	**2.640**	**3.616**
Local	**2.712**	**3.832**	**3.447**	**2.230**	**3.055**
Ishaqi1	**3.268**	**5.163**	**3.505**	**2.972**	**3.727**
Ishaqi2	**2.773**	**4.419**	**4.975**	**3.504**	**3.918**
Tarazan	**3.197**	**4.725**	**4.676**	**4.089**	**4.172**
L.S.D.	**0.076**				**0.038**
Mean	**3.137**	**4.447**	**4.120**	**3.087**	
L.S.D.	**0.039**				

Plant yield (gm)

The results of Table 8 indicate that there are highly significant differences between the levels of potassium fertilizer and the varieties and the interaction between them in the trait of the plant yield. The table shows that there are significant differences between the levels of potassium fertilizer, as the low fertilizer level (o.1) exceeded the highest yield per plant of 109.14 g, followed by the medium fertilizer level (0.2) with a mean yield per plant it reached 100.80 g, while the lowest mean plant yield reached 61.87 g for plants with a high level of potassium fertilizer (0.3). The reason for the superiority of the 0.1 ton K ha^{-1} fertilizer level in trait of plant yield is attributed to its superiority in most growth traits. It had the highest plant height of 221.87 cm and the highest number of leaves was 31.20 leaf plant^{-1} and the highest leaf area index of 5.537, which enabled it to excel with the highest disc weight of 188.22 g. This was accompanied by the lowest number of days for physiological maturity of 94.00 day, which resulted in its superiority with the highest crop growth of 4.447 g per plant day^{-1} (Tables 1, 2, 3, 4, 6, and 7) These results are consistent with what **Zaki et al. (2023)** found in their study on the sunflower, as they showed that adding potassium at moderate levels led to a significant increase in individual plant yield and seed yield compared to no addition or high addition. They explained that an excessive increase in potassium may lead to nutritional imbalance and reduce the efficiency of utilization of other elements, which negatively affects growth and yield.

The varieties differed significantly in the trait of individual plant yield. The Tarazan variety excelled with the highest mean plant yield of 95.08 g, followed by the two varieties Aqmar and Ishaqi1 with mean plant yields that did not differ significantly between them, amounting to 89.28 and 89.26 g, respectively, while the lowest plant yield was for the Ishaqi2 variety with a mean of 76.99 g, and the local variety did not differ significantly from it with a mean yield of 78.48. g. The reason for the superiority of the Tarazan variety in the plant trait is due to its superiority with the highest disc weight of 172.65 g (Table 4), and the highest crop growth rate of 4.172 gm plant day^{-1}. The results agree with what **Hassan (2016)** and **Ada (2023)** indicated, which is the presence of significant differences between the genotypes in the plant yield, as the G-4 variety excelled by giving the highest yield of 94.6 g plant^{-1} compared to the rest of the varieties.

Table (8) also shows that the varieties responded in a highly significant way to fertilization levels. The response was mostly towards an increase in the yield of the plant when adding potassium fertilizer, to the level of 0.2 ton K ha^{-1}, while the yield of the plant decreased at the fertilizer level of 0.3 ton K ha^{-1} compared to the 0.0 ton K ha^{-1} treatment for most varieties, the highest plant yield was for the interaction treatment between the Tarazan variety and the 0.1 ton K ha^{-1} fertilizer treatment was with a mean of 131.79 g, while the lowest mean yield for the plant was for the interaction treatment between the local variety and the contrpl treatment with a mean of 40.57 g.

Table 8. Plant yield (gm) of sunflower varieties as affected by potassium levels (Spring 2025)

varieties	levels of potassium fertilizer (ton K ha^{-1})				
	0.0	**0.1**	**0.2**	**0.3**	**Mean**
Aqmar	**76.41**	**107.51**	**97.48**	**75.71**	**89.28**
Local	**40.57**	**101.79**	**109.25**	**62.32**	**78.48**
Ishaqi1	**83.18**	**107.56**	**105.77**	**60.53**	**89.26**
Ishaqi2	**74.81**	**97.04**	**80.23**	**55.90**	**76.99**
Tarazan	**82.47**	**131.79**	**111.17**	**54.88**	**95.08**
L.S.D.	**4.97**				**2.49**
Mean	**71.49**	**109.14**	**100.80**	**61.87**	
L.S.D.	**3.06**				

Genetic parameters at the potassium fertilizer level of 0.0 ton K ha^{-1}

Table 9 shows the results of some genetic parameters for the studied traits at the fertilization level of 0.0 ton K ha^{-1}. The standard error values were very low for all traits. The low standard error (SE) values indicate that the trait data are similar and that they are close to the arithmetic mean. The table also shows that the values of the coefficient of variation (CV) were low (less than 20), and this is evidence of the homogeneity of the samples of .the studied traits

Table (9) shows that the values of genetic variation were greater than the environmental variation in all the studied traits, which indicates that the variation existing between the varieties was mainly due to genetics, with a small influence of the environment. The ratio of genetic to phenotypic variation was large for the studied traits (plant height, number of leaves, leaf area index, disc weight, weight of 500 seeds, DTM, CGR, and plant yield) because the values of genetic variation were higher than environmental, and their proportion of variation was the environmental value is more than 1. Its value ranged from 11.28 for the plant yield to 6111.11 for the trait of TDM. The genetic variation coefficient (GCV) values for all the studied traits, whose genetic variation was high and constituted a large percentage of the phenotypic variation, were close to the phenotypic variation coefficient (PCV) values, indicating the extent to which the genetic variation represents the phenotypic variation (it constitutes the largest proportion of it) its control over the traits and its responsibility the biggest is about the transmission of a trait, and that these traits are slightly affected by the environment.

Since phenotypic traits are the result of the influence of genetic factors and environmental factors and the interaction between them, therefore we find that the heritability of these traits differs according to the differences in these factors and the degree of their influence on the trait. The heritability rate varied and ranged from 92.3% for the trait of LAI to 99.9% for the trait of DTM. It is considered a high heritability rate, because all the traits .had high genetic variation and a very high percentage of phenotypic variationThe amount of the heritability rate indicates the confidence rate that through it, the genetic makeup can be distinguished from its phenotypic expression. These results are consistent with what **Hassan (2019)** and **Holland et al. (2021)** indicated about the difference in the degree of genetic control between quantitative traits depending on their physiological nature and response to the environment

Table 9. Some genetic parameters for the studied traits in sunflower under the fertilizer level of 0.0 ton ha^{-1} (spring 2025).

traits	SE	C.V	$\sigma^2 p$	$\sigma^2 g$	$\sigma^2 e$	σ^{2g}/σ^{2e}	P.C.V	G.C.V	h^2.b.s
plant height	2.063	1.608	355.100	342.333	12.767	26.81	8.483	8.329	0.964
number of leaves	0.489	3.038	9.900	9.183	0.717	12.81	11.291	10.875	0.928
leaf area index	0.115	5.091	0.509	0.470	0.039	12.05	18.303	17.580	0.923
disc weight	0.821	0.985	797.662	795.640	2.022	393.49	19.556	19.532	0.997
500 seeds weight	0.749	4.275	22.453	20.772	1.681	12.36	15.622	15.026	0.925
days to maturity,	0.020	0.050	5.5009	5.500	0.0009	6111.1	2.495	2.495	0.999
crop growth rate	1.492	5.590	274.18	267.509	6.676	40.07	35.824	35.385	0.976
plant yield	2.993	7.253	330.134	303.251	26.883	11.28	25.416	24.359	0.919

Genetic parameters at the potassium fertilizer level of 0.1 ton K ha^{-1}

The results of Table (10) for some genetic parameters of the studied traits in sunflower under the fertilization level of 0.1 ton K ha^{-1} show that the SE values were low for all traits, ranging between 0.039 and 1.877, which indicates the uniformity of the data and its closeness to the arithmetic mean, this confirms what **Falconer and Mackay (2020)** indicated that the low standard error reflects the homogeneity of the samples and the accuracy of the statistical estimate. The table also shows that the values of the CV were low for all the studied traits and they were all less than 20%. This is evidence of the homogeneity of the samples and the lack of random variation, which enhances the reliability of the experimental results and the accuracy of the measurements, and this is consistent with what was mentioned by **Singh and Kumar 2022**.

The results showed that the values of genetic variance (σ^2g) were higher than the values of environmental variance (σ^2e) in all the traits studied, which indicates that the variance between the genotypes is mainly due to genetic factors with a limited influence of the environment. Also, the rise in the ratio of σ^2g/σ^2e to more than the correct one for all traits confirms the control of the genetic factor on the phenotypic expression of these traits. Under this level of potassium fertilization, the values of the GCV approached the values of PCV in all studied traits, which indicates that the bulk of the phenotypic variation results from genetic variation, and that the influence of environmental factors was limited. This convergence indicates the possibility of improving these traits through selection, especially if appropriate fertilization levels are available that help reveal the true genetic differences. Broad-sense heritability (**h^2.b.s)** values were high for most of the studied traits, ranging between 68.7% for the number of days to physiological maturity trait and (98.9%) for the leaf area index trait, these values are high, which indicates that these traits are subject to a large degree of genetic control, and that the phenotypic expression represents the genetic structure with a high degree. The high heritability rate reflects high confidence in the possibility of direct selection based on phenotypic traits, and this is consistent with what **Holland et al. (2021)** indicated.

Table 10. Some genetic parameters for the studied traits in sunflower under the fertilizer level of 0.1 ton ha^{-1} (spring 2025).

traits	SE	C.V	$\sigma^2 p$	$\sigma^2 g$	$\sigma^2 e$	σ^{2g}/σ^{2e}	P.C.V	G.C.V	h^2.b.s
plant height	1.877	1.465	586.300	575.733	10.567	54.48	10.914	10.815	0.982
number of leaves	0.522	2.896	13.300	12.483	0.817	15.28	11.689	11.324	0.939
leaf area index	0.060	1.876	0.994	0.983	0.011	89.36	18.004	17.906	0.989
disc weight	1.556	1.447	299.999	292.738	7.262	40.31	9.301	9.188	0.976
500 seeds weight	0.873	4.614	40.601	38.316	2.285	16.77	19.451	18.895	0.944
days to maturity,	0.511	0.934	2.500	1.717	0.783	2.19	1.668	1.382	0.687
crop growth rate	0.039	1.537	0.276	0.272	0.005	54.40	11.824	11.723	0.983
plant yield	0.956	1.518	181.411	178.667	2.744	65.11	12.341	12.247	0.985

Genetic parameters at the potassium fertilizer level of 0.2 ton ha^{-1}.

The results of Table 11 for some genetic parameters of the studied traits in sunflower under the potassium fertilization level of 0.2 ton K ha^{-1} show that the SE values were low for most traits (ranging between 0.028-1.261), which indicates the convergence of the values and reflects the accuracy of the measurements. The table also shows that the values of the CV they were few (less than 20), and this is evidence of the homogeneity of the samples of studied traits.

The data showed that the values of σ^2g were higher than the values of σ^2e for most traits (plant height, disk weight, weight of 500 seeds, days to maturity (DTM), crop growth rate (CGR), and plant yield), which indicates that the phenotypic variance in these traits is due to a greater extent to genetic factors with limited environmental influence, and the high ratio of σ^2g/σ^2e for these traits (greater than 1) it confirms the control of the genetic factor on phenotypic expression under the fertilization level of 0.2 ton K ha^{-1}. While the number of leaves and LAI traits recorded σ^2g/σ^2e ratios less than 1, which indicates a greater environmental influence on the expression of these two traits. The results also showed that the values of the GCV were close to the values of the PCV in most traits, indicating that the largest part of the phenotypic variation resulted from genetic variation, and that the influence of environmental factors was limited under this level of fertilization, while clear differences were observed between the GCV and and PCV in leaf number and LAI traits, suggesting a greater environmental role in controlling them.

The table also showed that broad-sense heritability values were very high for traits whose genetic variance was higher than environmental variation, ranging between 86.4-99.5% for the two traits: weight of 500 seeds and crop growth rate, which indicates that these traits are controlled by genetics, and that phenotypic expression represents the genetic makeup to a high degree. In contrast, the traits number of leaves and LAI recorded low heritability values of 27.6 and 14.6%, respectively, which reflects their influence on factors. This is consistent with **Falconer and Mackay (2020)** and **Holland et al. (2021)** that traits with high heritability are more suitable for direct selection.

Genetic parameters at the potassium fertilizer level of 0.3 ton ha^{-1}.

The results of Table (12) for some genetic parameters of the studied traits under the fertilization level of 0.3 ton K ha-^{1} show that the standard error (SE) values were low for most traits, ranging between 0.017-3.263, which indicates the closeness of the values to the arithmetic mean and the lack of dispersion between the data. The results also showed that the coefficient of variation (CV) values were low for most traits. This is evidence of the homogeneity of the samples of the studied traits.

The results showed that the genetic variance values were higher than the environmental variance values for all the studied traits (plant height, number of leaves, LAI, disc weight, 500 seed weight, DTM, CGR, and plant yield), which indicates that the bulk of the phenotypic variance in these traits is due to genetic factors with limited environmental influence, and the high ratio of $\sigma^2 g/\sigma^2 e$ for these traits (greater than 1) ranged between 1.23. And 663.75 for plant height and CGR traits, respectively, confirming the control of the genetic factor on phenotypic expression under this fertilization level. The results also showed a great convergence between the values of the GCV and the PCV for all traits. Broad-sense heritability values (h^2bs) were high for most of the studied traits, reaching 77.7, 99.1, 99.2, 96.7, 73.9 , 99.8 and 99.5% for the traits number of leaves, leaf area index, disc weight, weight of 500 seeds, DTM, CGR, and plant yield, respectively, which indicates that these traits are largely subject to genetic control and that the phenotypic expression reflects the genetic makeup with high accuracy, while the medium heritability for the plant height trait was 55.2%, which indicates an increasing influence of the environment on this trait. These results are consistent with **Falconer and Mackay (2020)** and **Holland et al. (2021)** that high heritability enhances the efficiency of direct selection based on phenotypic traits.

Table 11. Some genetic parameters for the studied traits in sunflower under the fertilizer level of 0.2 ton ha^{-1} (spring 2025).

traits	SE	C.V	$\sigma^2 p$	$\sigma^2 g$	$\sigma^2 e$	σ^{2g}/σ^{2e}	P.C.V	G.C.V	h^2.b.s
plant height	1.186	0.972	381.200	376.983	4.217	89.396	9.239	9.187	0.989
number of leaves	0.837	4.997	2.900	0.800	2.100	0.381	5.872	3.084	0.276
leaf area index	0.575	19.938	0.992	0.145	0.847	0.146	18.423	7.633	0.146
disc weight	0.959	1.013	557.931	555.173	2.758	201.296	14.402	14.366	0.995
500 seeds weight	1.261	6.972	35.177	30.406	4.771	6.373	18.932	17.601	0.864
days to maturity,	0.675	1.242	1.833	0.467	1.367	0.342	1.438	0.726	0.255
crop growth rate	0.028	1.191	0.474	0.471	0.002	235.5	16.704	16.661	0.995
plant yield	1.097	2.078	403.526	399.917	3.609	110.811	21.980	21.881	0.991

Table 12. Some genetic parameters for the studied traits in sunflower under the fertilizer level of 0.3 ton ha^{-1} (spring 2025).

traits	SE	C.V	$\sigma^2 p$	$\sigma^2 g$	$\sigma^2 e$	σ^{2g}/σ^{2e}	P.C.V	G.C.V	h^2.b.s
plant height	3.263	2.619	71.333	39.383	31.950	1.23	3.914	2.908	0.552
number of leaves	0.610	4.250	5.000	3.883	1.117	3.48	8.992	7.925	0.777
leaf area index	0.029	1.127	0.283	0.280	0.003	93.33	11.831	11.777	0.991
disc weight	0.605	0.778	129.584	128.485	1.099	116.91	8.449	8.413	0.992
500 seeds weight	0.474	2.598	20.655	19.982	0.673	29.69	14.391	14.155	0.967
days to maturity,	0.596	1.072	4.100	3.033	1.067	2.84	2.102	1.808	0.739
crop growth rate	0.017	0.944	0.532	0.531	0.0008	663.75	23.622	23.603	0.998
plant yield	0.921	2.238	522.277	519.734	2.543	204.38	32.073	31.995	0.995

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