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RESPONSE OF DIFFERENT GENOTYPES OF SUNFLOWER TO POTASSIUM FERTILIZER

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ABSTRACT
With the aim of evaluating the genetic performance of different sunflower varieties and testing them under different levels of potassium fertilizer, and determining which varieties give a high yield under the influence of the fertilizer, a field experiment was conducted at Research Station A in the Field Crops Department - College of Agricultural Engineering Sciences - University of Baghdad - Al-Jadriya, for the spring season of 2025. The land was prepared for planting by perpendicular plowing, harrowing and leveling according to recommendations, using an RCBD design with three replications and a split plot arrangement. The four fertilization levels (0, 100, 200 and 300 kg K ha^{-1}) represented the main plots, while the varieties (Aqmar, local, Ishaqi 1, Ishaqi 2 and Tarsan) represented the sub plots. The number of flowering days, stem diameter, leaf area, disc diameter, number of seeds $disc^{-1}$, fertility percentage, dry plant weight and yield per unit area were studied. The results showed that the 100 kg K fertilizer level per ha^{-1} superiority the highest yield amount at 5.821 tons ha^{-1} due to its early flowering by a period of (71.47 days), leaf area (1.052 m^2), disc diameter (23.33 cm), number of seeds (1531.5 seeds $disc^{-1}$), fertility percentage (92.53%), and total dry weight (421.17 g). The results also showed significant differences between varieties, with the Tarsan variety having the highest yield per unit area at 5.071 tons ha^{-1} due to its superior disc diameter (25.5 cm), number of seeds (1510.7 $disc^{-1}$ seeds), and dry plant weight (397.89 g). The results also showed that genetic variance was higher than environmental variance for most of the studied traits. Broad-sense heritability was high for these traits at all four fertilizer levels, ranging from 0.693 for fertility percentage at 300 kg K ha^{-1}, to 0.999 for the number of disc seeds at all four fertilizer levels and for total dry weight at 100 and 200 kg K ha^{-1}. However, the genetic variance for the number of flowering days at 0 kg K ha^{-1}, fertility percentage at 100 kg K ha^{-1}, and stem diameter and leaf area at 200 kg K ha^{-1} showed lower genetic than environmental variance, meaning that environmental variance accounted for the largest share of phenotypic variance. Consequently, the heritability broad-sense for the days number to flowering at 0 kg K ha^{-1} was moderate, reaching 0.429. And the remaining traits were low, reaching 0.352, 0.223 and 0.146 for the three traits respectively.

KEYWORDS: Sunflower, Heritability broad-sense, Potassium fertilizer

INTRODUCTION

The sunflower (*Helianthus annuus* L.) is an oilseed crop of widespread economic and nutritional importance globally. It is a source of seeds rich in beneficial oils and fatty acids, used in the food industry, and contributes to improving farmers' agricultural incomes. Furthermore, its use has expanded to include multiple food and industrial sectors, reinforcing the need to improve its productivity (Adeleke and Babalola, 2020). Potassium (K) is a major nutrient essential for crop growth. It participates in regulating osmotic pressure, transporting metabolic products, activating enzymes, and controlling stomatal opening and closing. These functions directly affect water use efficiency, plant tolerance to environmental stresses such as drought, seed quality and plumpness, and oil content (Xu et al., 2020). Despite widespread knowledge about the benefits of potassium fertilization, sunflower response to this fertilization varies considerably depending on soil nutrient availability, environmental conditions, fertilizer composition (K source and levels), and genotype, which differ in their efficiency at absorbing and utilizing nutrients (Magsi *et al.*, 2023). Laghari *et al*. (2023), in their study of five potassium fertilizer levels (0, 30, 60, 80, and 120 kg K ha^{-1} mixed with 5 tons of complete farm manure), observed that the 120 kg K ha^{-1} treatment yielded the highest yield of 2725.7 kg ha^{-1}. The 80 kg K ha^{-1} treatment yielded a similarly high 2556.7 kg ha^{-1}, due to their superior plant height (247.7 cm and 224.0 cm, respectively) and diameter. The stem reached 11.2 and 10.2 cm, the highest head diameter reached 48.5 and 44.7 cm, the highest number of seeds in the head reached 1971.3 and 1789.3 $head^{-1}$ seeds, the highest weight of the head seeds reached 69.5 and 52.5 g, the highest weight of 1000 seeds reached 34.0 and 29.0 g. Similarly, Magsi *et al*. (2023), in their study of six potassium fertilizer levels (0, 20, 40, 60, 80, and 100 kg K ha^{-1}), found that the 100 kg K ha^{-1} fertilizer treatment resulted in the highest yield of 2803.3 kg ha^{-1}. The 80 kg K ha^{-1} fertilizer treatment, with a yield of 2766.7 kg ha^{-1}, did not differ significantly. This was attributed to their superior performance in terms of plant height (255.0 cm and 253.0 cm, respectively), stem diameter (12.2 cm and 11.6 cm, respectively), head diameter (49.8 cm and 42.5 cm, respectively), number of seeds per head (2059.3 and 2055.0, respectively), and seed weight (74.5 g). The weight of 1000 seeds was 74.0 grams for the two levels respectively, and the highest weight of 1000 seeds was 38.0 and 36.3 grams for the two levels respectively. Al-Doori and AL-Delymi (2014) found, when studying three varieties of sunflower (Saturn, Gordis and Majak) under the influence of three levels of potassium fertilizer (0, 30 and 60 kg K ha^{-1}), that the Gordis variety had the highest yield per unit area, which reached 2.89 tons ha^{-1}, due to its having the highest plant height of 115.87 cm, the highest stem diameter of 2.11 cm, the highest leaf area of 3160.60 cm2, the highest disc diameter of 21.25 cm, the highest number of disc seeds of 1152.66 $disc^{-1}$ seeds, the highest weight of 1000 seeds of 74.97 g, and the highest fertility rate of 86.07%. They also found that the 30 kg K ha^{-1} fertilizer level excelled the other two levels with the highest yield per unit area, which reached 2.59 tons ha^{-1}, due to its having the highest plant height of 114.64 cm, the highest stem diameter of 2.28 cm, the highest leaf area of 2993.70 cm^2, the highest disc diameter of 20.77 cm, the highest number of disc seeds of 1166.05 seeds $disc^{-1}$, the highest weight of 1000 seeds of 72.97 g, and the highest fertility rate of 84.91%. The 60 kg K ha^{-1} fertilizer level did not differ from it with a fertility rate of 84.35%. Jamro *et al* (2018) also found, when studying eight sunflower genotypes (Samsung2, Mehran2, Ho-1, Melabour, Samsung30, Valugur, Chinika and Sputnik) under the influence of two potassium levels (0 and 50 kg K ha-1), that the Ho-1 genotype had the highest seed yield of 2409.5 kg ha^{-1}, due to its superiority in the highest disc diameter (20.20 cm), and the highest number of seeds $head^{-1}$ (2039.7) seeds $head^{-1}$. Likewise, the 50 kg ha^{-1} potassium fertilizer level had the highest seed yield of 2065.8 kg ha^{-1}, due to its superiority in the highest disc diameter of 17.45 cm, and the highest number of seeds per head of 1763.1 seeds $head^{-1}$. The research aims to evaluate the effect of different levels of potassium fertilization on the growth and yield traits of several sunflower varieties, and to determine the optimal economic fertilization level for each variety, while studying some genetic parameters.

MATERIALS AND METHODS

To evaluate sunflower genotypes at four potassium fertilizer levels and to estimate some genetic parameters, in order to determine which genotype gives the best yield under potassium fertilizer influence, a field experiment was conducted at Research Station A, College of Agricultural Engineering Sciences, University of Baghdad/Al-Jadriya, during the spring season of 2025. Field operations at the experimental location were carried out, including land preparation, perpendicular plowing, harrowing, and leveling, according to recommendations. A split-plot arrangement was used within a randomized Complete Block Design (RCBD) with four replications. The main plots included the fertilization levels (0, 100, 200, and 300 kg K ha^{-1}), while the subplots included the genotypes (Aqmar, local, Ishaqi 1, Ishaqi 2, and Tarsan). The experiment comprised 80 experimental units in the form of plots, each plot containing five rows, 3 meters long, with a spacing of 75 cm between rows. The seeds were sown on 15/ 3/2025, with three seeds placed in each hole. They were thinned to one plant at the two-leaf stage. Potassium sulfate fertilizer (41.5% K) was used as a potassium source, added in one application before planting according to the quantities mentioned above. Urea fertilizer (46% N) was added as a nitrogen source (350 kg N ha^{-1}) in three batches (first: 2 weeks after germination, second: at the elongation stage, and third: at the beginning of flowering). Weeds were removed manually, and other crop management operations were carried out as needed. Five average plants were taken randomly from each experimental unit. The traits of the number of days to flowering, stem diameter (mm), leaf area(cm^2), disc diameter(cm), number of seeds $disc^{-1}$, fertility percentage (fertility percentage = (number of filled seeds / total number of seeds) × 100), dry plant weight(gm), and yield per unit area (ton ha^{-1}) were measured.

Statistical Analysis

The data were statistically analyzed using Microsoft Excel and Genestat software according to a split-plot ANOVA (Analysis of Variance) design (RCBD). Significance was tested using the F-test at a probability level of 0.05, and the means were compared using the Least Significant Difference (LSD) method at a probability level of 0.05.
Estimation of the Coefficient of Variance (CV) and Some Genetic Parameters
The Coefficient of Variance (CV%) was calculated to estimate homogeneity among the samples. Genotypic, environmental, phenotypic, and broad-sense heritability were estimated for each fertilization level using SPAR 2.0 software for genetic analysis, as described by Singh and Chaudhary (2010). Genetic, environmental, and phenotypic variances

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

$\sigma^2 E = MSe$

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

Where:

MSg: Mean squared of genotypes

MSe: Mean squared of experimental error

r: Number of replications

$\sigma^2 G$, $\sigma^2 E$, and $\sigma^2 P$ = Genotypic, environmental, and phenotypic variances, respectively. The genotypic variation coefficient (GCV) and phenotypic variation coefficient (PCV) were estimated as follows:

$$GCV\% = \frac{\sqrt{\sigma^2 g}}{\bar{x}} \times 100$$

$$PCV\% = \frac{\sqrt{\sigma^2 p}}{\bar{x}} \times 100$$

The broad sense heritability ($h^2_{b.s}$) was calculated using the following equation:

$h^2.b.s = (\sigma^2 g / \sigma^2 p) \times 100$

Heritability less than 40% is considered low, between 40-60% is considered medium, and greater than 60% is considered high (Al-Adhari, 1982).

RESULTS AND DISCUSSION

Number of Days from Planting to 75% Flowering

Table 1 shows highly significant differences between potassium fertilizer levels, varieties, and their interaction in the number of days to flowering. The table demonstrates that potassium fertilization at different levels effectively reduced the number of days to flowering. This trait was significantly affected by the different fertilizer levels. Plants treated with the three fertilizer levels (100, 200, and 300 kg K ha^{-1}) reached flowering earlier, with the shortest number of days being 71.47, 72.40, and 73.60 days, respectively, compared to plants in the control treatment (0.00 K ha^{-1}). The control plants reached 75% flowering later, with the longest number of days being 75.40, and flowering was delayed by 3.93, 3.00, and 1.80 days, respectively, compared to the plants in the three fertilizer levels. The reason for the earlier flowering of plants treated with potassium may be... It completed its vegetative growth faster than plants that did not receive it, and reached the reproductive stage because potassium plays many important roles for the plant. It is at the forefront of the major nutrients that control the mechanism of opening and closing stomata and regulating the osmotic potential of the plant. It helps in water absorption and permeability, acts as an enzyme activator, reduces lodging due to cellulose synthesis, reduces respiration, helps in carbon metabolism, transports sugars and starches, and increases the plant's protein content. This is consistent with Shamran and Al-Mughair (2022) , who found significant differences between potassium fertilizer levels in the number of days to 50% flowering, and the 120 k /ha^{-1} level was superior in that its plants reached flowering earlier with the fewest number of days, which was 88.96 days. The varieties differed significantly in reaching 75% flowering, as the Ishaqi 1 variety was superior in the early arrival of its plants to reach 75% flowering in a number of days of 70.00 days, followed by the local variety whose plants reached flowering in a number of days of 73.50 days, and the Tarsan variety did not differ significantly from it in a number of days of 74.08 days, while the two varieties Aqmar and Ishaqi 2 were delayed in the arrival of their plants to flowering with an average number of days that did not differ significantly, which was 75.75 and 75.25 days for the two varieties respectively. The reason for the difference of the varieties in these traits is the difference in the genetic nature of the genotype or variety. This result is consistent with Hassan *et al.* (2019), who found differences between the genotypes of sunflowers in the number of days from planting to flowering, it agrees with what Alhayderi and Hassan (2022) found, who found that the varieties differed significantly in the number of days to reach flowering, and that the Ishaqi 1 variety was the earliest variety with a number of days, reaching 67.58 days. It does not agree with what Elewi (2020) found, which indicated that the sunflower varieties (Ishaqi 1, Ishaqi 2, Aqmar, and Tarsan) did not differ significantly in the trait of the number of days to 75% flowering. Table (1) also shows that the varieties responded very significantly to the fertilization levels. The direction of the response was to reduce the number of days to reach 75% flowering when potassium fertilizer was added compared to the control treatment. The greatest response was for the Ishaqi 1 variety, as the number of days decreased at the 300 kg ha^{-1} fertilizer level by 8.00 days compared to the control treatment (without potassium fertilization).

Stem Diameter (mm)

Table 1 also indicates no significant differences between potassium fertilizer levels, but highly significant differences exist between varieties and their interaction with fertilizer levels in stem diameter. The table data shows that fertilizer levels did not significantly affect stem diameter, which contradicts the findings of Laghari *et al.* (2023), who found significant differences between potassium fertilizer levels in stem diameter. The 120 kg K ha^{-1} level resulted in the highest stem diameter of 11.2 cm, while the 80 kg K ha^{-1} level did not differ significantly, with an average diameter of 10.2 cm. The table also shows a highly significant difference in stem diameter among the varieties. Plants of the Ishaqi 1 variety had the highest average stem diameter at 28.67 mm, followed by Ishaqi 2 and Tarsan varieties at 28.42 and 28.58 mm, respectively. The lowest average stem diameter was 26.58 mm for the local variety, followed by Aqmar variety at 27.00 mm. This difference is attributed to genetic variation among the varieties, as well as varying environmental influences. This finding aligns with the results of Elewi and Zeboon (2020), who found that Aqmar had the highest average stem diameter at 3.45 cm, while Ishaqi 1 had the lowest. It also agrees with Al-Hayderi's (2021) findings regarding stem diameter variation, with Ishaqi 2 exhibiting the highest diameter. The stem reached 2.75 cm. The table also shows that the varieties responded highly and significantly to the fertilization levels. The response was towards an increase in stem diameter with the addition of potassium fertilization. The highest stem diameter was observed in the interaction treatment between the Ishaqi 2 variety and the 300 kg K ha^{-1} fertilizer treatment, with an average of 32.00 mm. The Tarsan variety interaction treatment at the same fertilizer level showed a similar average of 31.00 mm. The lowest average stem diameter was 24.67 mm in the interaction treatment between the Aqmar variety and the control treatment (0 kg K ha^{-1}).

Table 1. Means number days to 75% flowering and stem diameter of oilseed varieties of sunflower under the influence of potassium fertilizer for the spring season of 2025.

Varieties	days to 75% flowering					stem diameter				
	0 $kgkha^{-1}$	100 $kgkha^{-1}$	200 $kgkha^{-1}$	300 $kgkha^{-1}$	Means	0 $kgkha^{-1}$	100 $kgkha^{-1}$	200 $kgkha^{-1}$	300 $kgkha^{-1}$	Means
Ishaqi 1	75.00	67.00	71.00	67.00	70.00	28.67	29.67	28.00	28.33	28.67
Ishaqi 2	77.00	71.00	76.00	77.00	75.25	26.67	29.33	25.67	32.00	28.42
Aqmar	76.00	75.00	76.00	76.00	75.75	24.67	26.33	29.00	28.00	27.00
Tarsan	74.00	73.33	75.00	74.00	74.08	29.00	25.33	29.00	31.00	28.58
Local	75.00	71.00	74.00	74.00	73.50	26.33	25.33	29.33	25.33	26.58
$L.S.D_{0.05}$	1.80				0.90	2.30				1.15
Means	75.40	71.47	72.40	73.60		27.07	27.20	28.20	28.93	
$L.S.D_{0.05}$	0.42					N.S				

Leaf Area (m² plant^{-1})

Table 2 shows highly significant differences between potassium fertilizer levels and varieties, as well as the interaction between them, in leaf area. The table indicates that potassium fertilization at different levels increased leaf area. The lowest fertilizer level (100 kg K ha^{-1}) resulted in the highest leaf area, averaging 1.052 m² plant^{-1}, followed by the second fertilizer level (200 kg K ha^{-1}) with an average of 0.949 m² plant^{-1}. The highest fertilizer level (300 kg K ha^{-1}) did not differ significantly, averaging 0.855 m². The lowest average leaf area was observed in the control treatment (no potassium fertilizer), at 0.740 m² plant^{-1}. The reason for the highest leaf area with the first fertilizer level is attributed to the earlier flowering of the plants (Table 1). The varieties had significant differences in leaf area. The Ishaqi 1 variety had the highest average leaf area at 0.954 m² plant^{-1}, followed by Ishaqi 2 and Tarsan varieties with averages of 0.945 and 0.937 m² plant^{-1}, respectively. The lowest average leaf area was observed in the local variety at 0.821 m²/plant-1, followed by Aqmar variety at 0.838 m² plant^{-1}. These results are consistent with Hassan *et al.* (2019), who found significant differences in leaf area between sunflower varieties and across two growing seasons. They also consistent with Elewi and Zeboon (2020), who found significant differences in leaf area between varieties, with Aqmar exhibiting the highest average (1.033 m²) and Ishaqi 2 the lowest. This finding is also consistent with Alhayderi and Hassan (2022) found that the varieties differed significantly in leaf area, with the Ishaqi 2 variety being the superior in this trait, averaging 0.91 m². Table (2) also shows that the varieties responded significantly to the fertilization levels. The response was towards an increase in leaf area with the addition of potassium fertilizer compared to the control treatment (without potassium fertilization). Generally, the highest average leaf area was at a fertilizer level of 100 kg K ha^{-1}, then it decreased as the fertilizer level increased up to 300 kg K ha^{-1}. The highest average leaf area was 1.200 m² plant^{-1} for the interaction treatment between the Tarsan variety and the 100 kg K ha^{-1} fertilizer treatment, while the lowest average leaf area was 0.597 m² plant^{-1} for the interaction treatment between the Aqmar variety and the control treatment. The response magnitude between this interaction treatment and the interaction treatment of the same variety with the 100 kg K ha^{-1} fertilizer treatment was 77.554%.

Disc Diameter (cm)

The results in Table 2 indicate highly significant differences between potassium fertilizer levels, varieties, and interaction in disc diameter. The table shows significant differences between potassium fertilizer levels. The 100 kgK h^{-1} fertilizer level resulted in an average disc diameter of 23.33 cm, while the 200 kg K h^{-1} fertilizer level did not differ significantly, resulting in an average disc diameter of 22.87 cm. However, the highest potassium fertilizer level (300 kg K h^{-1}) resulted in the lowest average disc diameter of 19.66 cm. The reason for the superiority of the 100 kgK/h^{-1} fertilizer level in this trait is its superiority in growth traits such as flowering and leaf area (Tables 1 and 2). This agreed with Lagari *et al.* (2023), who found significant differences between potassium fertilizer levels in disc diameter, with the 120 kg k h^{-1} fertilizer level having the highest diameter. 48.5 cm, and the 80 kg K ha^{-1} level did not differ significantly, with an average diameter exceeding 44.7 cm. Therefore, it is sufficient to align with Babar *et al.* (2024), who found significant differences between potassium fertilizer levels in disc diameter, and the 62 kg K ha^{-1} level, with a maximum disc diameter of 28.00 cm. The varieties differed significantly in disc diameter, with the Tarsan variety exhibiting the highest average disc diameter of 25.50 cm. The local variety had an average disc diameter of 20.50 cm, while the remaining three varieties did not differ significantly from the averages of 21.75, 21.42, and 20.92 cm, respectively. The variation in disc diameter among the varieties was attributed to the diverse differences in this characteristic. This finding contradicts that of Alhayderi and Hasan (2022), who found that the varieties differed significantly in disc diameter, with the Tarsan variety having the highest disc diameter of 22.22 cm, while the Ishaqi 2 variety did not differ significantly, with a disc diameter of 22.17 cm.Table (2) also shows that the varieties responded very significantly to the fertilization levels. The response was mostly towards increasing the disc diameter when potassium fertilizer was added up to the level of 200 kg K ha^{-1}, while the disc diameter decreased at the fertilizer level of 300 kg K ha^{-1} compared to the treatment of 0 kg K ha^{-1}. The highest disc diameter was for the two interaction treatments between the Tarsan variety and the fertilizer treatments of 100 and 200 kg K ha^{-1}, with an average of 26.67 cm for both. The interaction treatment for the same variety at the 300 kg K ha^{-1} treatment did not differ significantly from them, while the lowest average disc diameter was for the interaction treatment between the Ishaqi 1 variety and the fertilizer treatment of 300 kg K ha^{-1}, with an average of 17.00 cm.

Table 2. Means leaf area and disc diameter of oilseed varieties of sunflower under the influence of potassium fertilizer for the spring season of 2025.

Varieties	Leaves area (m^2)					disc diameter(cm)				
	0 kgha^{-1}	100 kgha^{-1}	200 kgha^{-1}	300 kgha^{-1}	Means	0 kgha^{-1}	100 kgha^{-1}	200 kgha^{-1}	300 kgha^{-1}	Means
Ishaqi 1	0.873	1.100	1.000	0.843	0.954	24.00	19.00	25.67	17.00	21.42
Ishaqi 2	0.810	1.170	0.820	0.980	0.945	20.00	23.67	21.67	18.33	20.92
Aqmar	0.597	1.060	0.917	0.780	0.838	23.33	24.67	20.67	18.33	21.75
Tarsan	0.600	1.200	1.017	0.930	0.937	23.33	26.67	26.67	25.33	25.50
Local	0.820	0.730	0.993	0.740	0.821	20.33	22.67	19.67	19.33	20.50
L.S.D $_{0.05}$	0.162				0.081	1.69				0.85
Means	0.740	1.052	0.949	0.855		22.20	23.33	22.87	19.66	
L.S.D $_{0.05}$	0.103					0.91				

Number of disc seeds (seeds disc^{-1})

The results in Table 3 indicate highly significant differences between potassium fertilizer levels, varieties, and their interaction in the number of disc seeds trait. The table shows significant differences between potassium fertilizer levels. The 100 kg K ha^{-1} fertilizer level resulted in the highest average number of seeds per disc, reaching 1531.5 seeds disc^{-1}. This was followed by the 200 kg K ha^{-1} fertilizer level, with an average number of disc seeds of 1308.5 disc-1 seeds. Plants treated with 300 kg K ha^{-1} fertilizer gave the lowest average number of disc seeds, at 822.1 seeds disc^{-1}. The reason for the superiority of the 100 kg K ha^{-1} level in this trait is its superiority in disc diameter (Table 2), which increased its area and consequently the number of grains. This is consistent with Laghari *et al.* (2023), who found significant differences between potassium fertilizer levels in the number of seeds in the disc was a significant. The 120 kg K ha^{-1} level showing the highest number of seeds (1971.3 seeds disc^{-1}). The 80 kg K ha^{-1} level did not differ significantly, with an average seed count of 1789.3 seeds disc^{-1}. This finding is consistent with Shamran and Al-Mughair (2022), who found significant differences in disc seed count between potassium fertilizer levels, with the 120 kg K ha^{-1} level showing the highest number of seeds (1202.29 seeds disc^{-1}). It also aligns with Babar et al. (2024), who found significant differences in disc seed count between potassium fertilizer levels, with the 62 kg K ha^{-1} level showing the highest number of seeds (1063 seeds disc^{-1}).

The number of seeds in the disc was significantly higher at 120 kg K ha^{-1}. The varieties differed significantly in the number of disc seeds. The Tarsan variety had the highest disc number, with 1510.7 seeds disc^{-1}, followed by the Local, Ishaqi 2, and Ishaqi 1 varieties with average disc number of 1155.2, 1127.5, and 1098.4 seeds disc^{-1}, respectively. The lowest disc number was for the Aqmar variety, with an average of 954.9 seeds disc^{-1}. This difference in the varieties is attributed to their different genotypes and is also related to the number of ovary origins, which in turn is linked to the disc number. This number is associated with increasing disc diameter, in which the Tarsan variety excelled. This finding is consistent with Hassan *et al.* (2019), who found that the two studied varieties differed significantly in disc number across the two study seasons, with the Aqmar variety surpassing the Shamous variety by 1024 and 952 seeds disc^{-1}, respectively. It is also consistent with Elewi' (2020), findings demonstrated the superiority of the Aqmar variety, which yielded the highest average for the trait. This finding was also consistent with that of Alhayderi and Hassan (2022), who found that the varieties differed significantly in the number of seeds in the disc, with the Tarsan variety exhibiting the highest seed count at 1772.2 days.Table (3) also shows that the varieties responded very significantly to the fertilization levels. The response was mostly towards increasing the number of disc seeds when potassium fertilizer was added at levels of 100 and 200 kg K ha^{-1}, while the number of disc decreased at the level of 300 kg K ha^{-1} compared to the treatment of 0 kg K ha-1. The highest number of disc seeds was for the interaction treatment between the Tarsan variety and the 100 kg K ha^{-1} fertilizer treatment, with an average of 2059.3 seeds disc^{-1}, followed by the interaction treatment for the same variety at the 200 kg K ha^{-1} fertilizer treatment, with an average of 1860.7 seeds disc^{-1}. The lowest average number of seeds was 658.3 seeds disc^{-1} for the interaction treatment between the local variety and the 300 kg K ha^{-1} fertilizer treatment.

The percentage of fertility (%):

Table 3 also indicates significant differences between potassium fertilizer levels, varieties, and their interaction in the fertility percentage of sunflower seeds. The table shows that potassium fertilization at different levels increased seed fertility. This trait was significantly affected by the potassium fertilization level. Plants treated with the first level of potassium fertilizer (100 kg K ha⁻¹) showed the highest fertility with an average of 92.53%. Plants treated with the second level of potassium fertilizer (200 kg K ha⁻¹) showed no significant difference with an average of 92.14%. The lowest seed fertility percentage was observed in the control treatment with an average of 85.87%. Plants treated with the highest level of potassium fertilizer (300 kg K ha⁻¹) showed no significant difference with an average fertility percentage of 85.55%. The reason for the superiority of the 100 kg K ha^{-1} level in terms of fertility is that the plants that received potassium completed their vegetative growth faster than the plants that did not receive it, and reached the reproductive stage in fewer days (Table 1). It also excelled in terms of disc diameter (Table 2), which increased its area and consequently increased the number of seeds in it (Table 3). The table also shows that the varieties differed significantly in fertility percentage, with the Aqmar variety having the highest average fertility percentage at 90.53%. The Tarsan, Ishaqi 1, and Ishaqi 2 varieties did not differ significantly from this, with averages of 90.06%, 88.64%, and 88.71%, respectively. The lowest average seed fertility percentage was for the local variety at 85.92%. This is attributed to the differences in the genotypic factors of the varieties. This result is consistent with what Hassan *et al.* (2019) indicated, finding that the two studied varieties, Shamous and Aqmar, differed significantly in fertility percentage, with Aqmar having the highest fertility percentage of 94.58% and 97.50% for the two growing seasons, respectively. It also agrees with Al-Haideri (2021), who found that the highest fertility percentage was recorded by the Ishaqi 1 variety at 94.74%, with no significant difference between the other two varieties. Tarsan and Flami had fertility percentage of 94.46% and 94.20%, respectively. This result did not agree with those of Elewi (2020), whose study showed no significant difference between the varieties in this trait.Table (3) also shows that the varieties responded significantly to fertilization levels. The response was towards increased fertility with the addition of potassium fertilizer, especially at the first and second levels (100 and 200 kg K ha⁻¹). The highest fertility rate was observed with the interaction between the local variety and the fertilizer treatment (200 kg K ha⁻¹), with an average of 98.38%. This was not significantly different from the interaction between the same variety and the fertilizer treatment (100 kg K ha⁻¹), with an average fertility rate of 97.39%. The lowest fertility rate was observed with the interaction between the same variety and the control treatment, at 71.57%. This indicates that the local variety had an increased fertility rate. Fertility increased by 26.81% and 25.81% when potassium fertilizer was added at levels of 100 and 200 kg K ha^{-1}, respectively.

Table 3. Means Number of disc seeds (seeds $disc^{-1}$) and the percentage of fertility (%) of oilseed varieties of sunflower under the influence of potassium fertilizer for the spring season of 2025.

Varieties	Number of disc seeds (seeds $disc^{-1}$)					The percentage of fertility (%)				
	0 $kgkha^{-1}$	100 $kgkha^{-1}$	200 $kgkha^{-1}$	300 $kgkha^{-1}$	Means	0 $kgkha^{-1}$	100 $kgkha^{-1}$	200 $kgkha^{-1}$	300 $kgkha^{-1}$	Means
Ishaqi 1	885.3	1383.7	1361.7	762.7	1098.4	83.10	92.58	91.43	87.44	88.64
Ishaqi 2	987.0	1423.7	1171.3	928.0	1127.5	86.80	88.05	88.89	91.12	88.71
Aqmar	971.3	1090.0	1065.7	692.7	954.9	94.33	94.23	87.45	86.10	90.53
Tarsan	1054.0	2059.3	1860.7	1068.7	1510.7	88.53	90.40	94.56	86.76	90.06
Local	1178.7	1700.7	1083.0	658.3	1155.2	71.57	97.38	98.38	76.33	85.92
L.S.D $_{0.05}$	13.6				6.8	4.45				2.22
Means	1015.3	1531.5	1308.5	822.1		84.87	92.53	92.14	85.55	
L.S.D $_{0.05}$	8.3					2.03				

Dry Plant Weight (g)

The results in Table 4 indicate highly significant differences between potassium fertilizer levels, varieties, and their interaction in the dry plant weight (TDM) trait. The table shows significant differences between potassium fertilizer levels, with the 100 kg K ha⁻¹ fertilizer level resulting in the highest dry plant weight of 421.17 g, followed by the 200 kg K ha⁻¹ fertilizer level with an average dry plant weight of 387.38 g. The lowest average dry plant weight was 295.11 g for the control treatment (0 kg K ha⁻¹), and the high potassium fertilizer level (300 kg K ha⁻¹) did not differ significantly from this, with an average dry plant weight of 297.20 g. The reason for the superiority of the 100 kg K ha⁻¹ fertilizer level in this trait is its superiority in leaf area , disc diameter, the number of seeds in the disc and the fertility percentage (Tables 3, 4) . This agree with Babar *et al.* (2024), who found significant differences between potassium fertilizer levels in biological yield, with the 62 kg Kha^{-1} showing the highest biological yield of 11.363 kg ha⁻¹.The varieties differed significantly in terms of dry plant weight, with the Tarsan variety exhibiting the highest average dry germination weight of 397.98 g. This was followed by the Ishaqi 2, Aqmar, and Ishaqi 1 varieties, with averages of 367.40, 342.96, and 331.42 g, respectively. The local variety had the lowest dry plant weight, averaging 291.31 g.

The Tarsan variety's superiority in total plant dry weight is attributed to its higher average disc diameter and number of grains (Tables 2 and 3). This finding aligns with Elewi's (2020) report of significant differences in biological yield among the varieties, with Aqmar outperforming Ishaqi 2 and not showing significant differences.

Similarly, Al-Haideri (2021) also found significant differences in biological yield among the varieties, with Aqmar superiority Ishaqi 2. Tarsan had the highest dry weight, reaching 388.53 g.
Table (4) also shows that the varieties responded highly significantly to fertilization levels. The response was generally towards an increase in plant dry weight when potassium fertilizer was added, with the highest weight at the 100 kg K ha⁻¹ level. Plant weight decreased at the 300 kg K ha⁻¹ level compared to the 0 kg K ha⁻¹ treatment for all varieties except Ishaqi 2 and Tarsan. The highest dry weight was observed in the interaction treatment between Ishaqi 1 and the 100 kg K ha⁻¹ fertilizer treatment, with an average of 487.03 g. The lowest average dry weight was observed in the interaction treatment between the local variety and the 300 kg K ha⁻¹ fertilizer treatment, with an average of 220.75 g.

Yield per unit area (ton ha⁻¹)
Table 4 also indicates highly significant differences between potassium fertilizer levels, varieties, and their interaction in yield per unit area. The table shows significant differences between potassium fertilizer levels, with the 100 kg K ha⁻¹ fertilizer level having the highest yield per unit area at 5.821 tons ha⁻¹, followed by the 200 kg K ha⁻¹ fertilizer level with an average yield per unit area of 5.375 tons ha⁻¹. The lowest average yield per unit area was 3.300 tons ha⁻¹ for plants treated with the highest potassium fertilizer level (300 kg K ha⁻¹), while the control treatment had an average yield per unit area of 3.813 tons ha⁻¹. The superiority of the 100 kg K ha⁻¹ fertilizer level is attributed to its having the largest leaf area (1.052 m²) and the largest disc diameter. The disc diameter was 23.33 cm (Table 2), the highest number of disc seeds was 1531.5 disc^{-1} seeds, and the highest fertility rate was 92.53% (Table 3). This is also due to its having the highest plant dry weight of 421.17 g (Table 4). This is consistent with Laghari *et al* (2023), who found significant differences between potassium fertilizer levels in the total yield trait, with the 120 kgK/ha-1 level having the highest yield of 2725.7 kg ha^{-1}, and the 80 kgK ha^{-1} level not differing significantly from it with an average yield of 2556.7 kg ha^{-1}. This is also consistent with Babar *et al* (2024), who found significant differences between potassium fertilizer levels in the yield trait, with the 62 kgK/ha^{-1} level having the highest yield of 2976 kg ha^{-1}.
The varieties differed significantly in yield per unit area, with the Tarsan variety having the highest average yield of 5.071 tons ha⁻¹. This was followed by the Aqmar and Ishaqi 1 varieties, both with average yields of 4.761 tons ha⁻¹, which did not differ significantly from each other. The lowest yield per unit area was recorded by the Ishaqi 2 variety, with an average of 4.106 tons ha⁻¹, and the local variety had a similar average yield of 4.186 tons ha⁻¹. The superiority of the Tarsan variety in yield is attributed to its larger disc diameter 25.5 cm (Table ,2), the highest number of disc seeds (1510.7 seeds disc^{-1}, Table 3), and the highest dry plant weight 397.98 g (Table ,4). The Ishaqi 1 and Aqmar varieties also excelled in yield per unit area based on several traits, such as flowering, stem diameter, and fertility percentage, this result is consistent with the findings of Hassan et al. (2019), who found that the two studied varieties differed significantly in yield per unit area for the spring and fall seasons. It also aligns with Elewi (2020), who indicated significant differences in this trait, with the Ishaqi 2 variety exhibiting the highest average yield of 5.138 µg ha⁻¹. Similarly, it agrees with Alhayderi and Hassan (2022), who found significant differences between the varieties, with the Tarsan variety achieving the highest yield of 9.33 tons ha⁻¹.This finding is consistent with the results of Hassan et al. (2019), who found significant differences between the varieties. Table (4) also shows that the varieties responded very significantly to the fertilization levels. The response was mostly towards increasing the yield per unit area when potassium fertilizer was added, up to a level of 200 kg K ha^{-1}. The yield decreased at the fertilizer level of 300 kg K ha^{-1} compared to the treatment of 0 kg K ha-1 for most varieties. The highest yield per unit area was for the interaction treatment between the Tarsan variety and the fertilizer treatment of 100 kg K ha^{-1}, with an average of 7.029 tons ha^{-1}, followed by the interaction treatment of the same variety with the treatment of 200 kg K ha^{-1}, with an average of 5.929 tons ha^{-1}. The lowest average yield was for the interaction treatment between the local variety and the control treatment, with an average of 2.164 tons ha^{-1}.

Table 4. Means dry plant weight (gm) and Yield per unit area (ton ha⁻¹) of oilseed varieties of sunflower under the influence of potassium fertilizer for the spring season of 2025.

Varieties	Dry Plant Weight (g)					Yield per unit area (ton ha⁻¹)				
	0 kgkha^{-1}	100 kgkha^{-1}	200 kgkha^{-1}	300 kgkha^{-1}	Means	0 kgkha^{-1}	100 kgkha^{-1}	200 kgkha^{-1}	300 kgkha^{-1}	Means
Ishaqi 1	303.92	487.03	329.41	285.31	331.42	4.436	5.737	5.641	3.228	4.761
Ishaqi 2	257.85	413.92	462.66	335.18	367.40	3.990	5.176	4.279	2.981	4.106
Aqmar	351.01	397.06	375.63	248.15	342.96	4.075	5.734	5.199	4.038	4.761
Tarsan	313.30	442.49	439.52	396.59	397.98	3.399	7.029	5.929	2.927	5.071
Local	249.49	365.32	329.70	220.75	291.31	2.164	5.429	5.826	3.324	4.186
L.S.D $_{0.05}$	3.93				1.96	0.265				0.133
Means	295.11	421.17	387.38	297.20		3.813	5.821	5.375	3.300	

L.S.D $_{0.05}$	2.20		0.163	

Genetic Parameters
Heritability is defined as the control of genetic factors over a particular trait. Knowing the quantity of heritability for each trait is essential for adopting a specific breeding method and improving that trait. High heritability values in the broad sense are due to a high value of genetic variance compared to environmental variance, indicating that the majority of the variance will be due to genotype nature. Thus, the contribution of experimental error (environmental variance) to phenotypic variance will be low, meaning that there are high genetic differences influencing the trait (El-Hashash and Agwa, 2018). Heritability is denoted by the symbol h2, which equals the ratio of genetic variance to phenotypic variance. Genetic variation is one of the most fundamental factors for plant breeders, as it represents the basis upon which selection is founded. Therefore, crop improvement relies on estimating information about phenotypic, genotypic, and environmental variances, as well as the phenotypic and genotypic variation coefficients, and the degree of heritability in the broad sense.

Coefficient of Variance (C.V %) and Phenotypic Variance (σ^2P) at Fertilizer Levels of 0, 100, 200, and 300 kg K ha^{-1}
Table 5 shows that the values of the Coefficient of Variance (C.V) for some genetic parameters were very low (less than 20). This indicates the homogeneity of the samples for all studied traits at the four fertilization levels (0, 100, 200, and 300 kg K ha^{-1}), with the exception of leaf area at the 200 kg K ha^{-1} fertilizer level, where the Coefficient of Variance was high at 19.98, but still within the acceptable limit. Table 5, along with Table 6, also shows that the phenotypic variation (σ^2p) was high, mostly due to genetic variation (σ^2g), at all fertilizer levels and for all studied traits except for the number of the number of flowering days at a fertilizer level of 0 kg K ha^{-1}, the trait of the fertility percentage at a fertilizer level of 100 kg K ha^{-1}, and the traits of stem diameter and leaf area at a fertilizer level of 200 kg K ha^{-1}, whose phenotypic variation mostly came from environmental variation (σ^2e).

Table 5. Coefficient of variation (C.V%) and phenotypic variation (σ^2p) of the studied traits in sunflower at fertilizer levels of 0, 100, 200, 300 (kg K ha^{-1}) for the spring season of 2025.

Traits	C.V%				$\sigma^2 p$			
	0 kgkha^{-1}	100 kgkha^{-1}	200 kgkha^{-1}	300 kgkha^{-1}	0 kgkha^{-1}	100 kgkha^{-1}	200 kgkha^{-1}	300 kgkha^{-1}
Days to flowering (days)	**1.143**	**1.445**	**1.488**	**1.472**	**2.100**	**9.800**	**16.100**	**5.100**
Stem diameter(mm)	**2.237**	**3.219**	**8.479**	**3.091**	**3.433**	**5.100**	**6.067**	**7.500**
Leaf area (m)	**5.041**	**1.889**	**19.979**	**0.919**	**0.018**	**0.036**	**0.041**	**0.010**
Disc diameter (cm)	**3.769**	**3.628**	**6.001**	**4.782**	**4.000**	**8.533**	**9.233**	**16.667**
Seeds number disc^{-1}	**0.799**	**0.665**	**0.494**	**0.998**	**128025.0**	**144303.2**	**197662.9**	**91180.86**
Fertility percentage %	**1.391**	**4.124**	**1.047**	**3.999**	**72.582**	**22.483**	**20.084**	**38.153**
Dry plant weight(gm)	**0.935**	**0.801**	**0.562**	**0.826**	**1367.77**	**2144.023**	**3806.051**	**4930.076**
Yield per unit area (ton ha^{-1})	**7.253**	**1.518**	**2.078**	**2.238**	**0.939**	**0.516**	**1.148**	**1.486**

Genetic (σ^2g) and environmental (σ^2e) variation at fertilizer levels 0, 100, 200, 300 (kg K h^{-1})
Table 6 shows the genetic and environmental variance of the studied traits at the four fertilization levels (0, 100, 200, 300 kg K ha^{-1}). The table shows that the genetic variance (σ^2 g) was higher than the environmental variance (σ^2e) at all fertilizer levels and for all studied traits except for the traits of number of flowering days at the 0 kg K ha^{-1} fertilizer level, the percentage of fertility at the 100 kg K ha^{-1} fertilizer level, and stem diameter and leaf area at the 200 kg K ha^{-1} fertilizer level, where the environmental variance was higher than the genetic variance (σ2 g).

Table 6. Genetic (σ^2 g) and environmental (σ^2e) variation of the studied traits in sunflower at fertilizer levels of 0, 100, 200, 300 (kg K ha^{-1}) for the spring season of 2025.

Traits	$\sigma^2 g$				$\sigma^2 e$			
	0 kgkha^{-1}	100 kgkha^{-1}	200 kgkha^{-1}	300 kgkha^{-1}	0 kgkha^{-1}	100 kgkha^{-1}	200 kgkha^{-1}	300 kgkha^{-1}
Days to flowering (days)	0.900	8.733	14.900	3.900	1.200	1.067	1.200	1.200
Stem diameter (mm)	3.067	4.333	1.350	6.700	0.367	0.767	4.717	0.800
Leaf area (m)	0.017	0.035	0.006	0.010	0.001	0.0004	0.036	0.0001
Disc diameter (cm)	3.300	7.817	3.383	15.800	0.700	0.717	1.850	0.867

Seeds number disc^{-1}	127933.0	144213.2	197627	91131.06	91.883	90.067	35.400	49.800
Fertility percentage %	71.187	7.921	19.152	26.447	1.395	14.561	0.931	11.706
Dry plant weight(gm)	1365.155	2132.649	3801.3	4927.636	2.614	11.374	4.738	2.439
Yield per unit area (ton ha^{-1})	0.863	0.508	1.138	1.478	0.077	0.008	0.010	0.007

Genetic Coefficient of Variance (GCV%) and Phenotypic Coefficient of Variance (PCV%) at fertilizer levels of 0, 100, 200, and 300 kg K ha^{-1}

Table 7 shows that the (PCV) values for all studied traits were close to the (GCV) values at all four fertilizer levels. This indicates that genetic variance largely represents phenotypic variance, controls the traits, and is largely responsible for their transmission. These traits are minimally affected by the environment. However, for the traits of number of flowering days at 0 kg K ha^{-1} fertilizer level, fertility percentage at 100 kg K ha^{-1} fertilizer level, and stem diameter and leaf area at 200 kg K ha^{-1} fertilizer level, the GCV values were significantly lower than the PCV values, and environmental variance accounted for the largest share of their variation. Phenotypic heterogeneity, meaning that this trait is not inherited and is controlled by environmental factors.

Table 7. Genotypic (G.C.V%) and Phenotypic (P.C.V%) coefficients of variation for the studied traits in sunflower at fertilizer levels of 0, 100, 200, 300 (kg K ha^{-1}) for the spring season of 2025.

Traits	**P.C.V%**				**G.C.V%**			
	0 kgkha^{-1}	**100 kgkha^{-1}**	**200 kgkha^{-1}**	**300 kgkha^{-1}**	**0 kgkha^{-1}**	**100 kgkha^{-1}**	**200 kgkha^{-1}**	**300 kgkha^{-1}**
Days to flowering (days)	**1.923**	**4.380**	**5.452**	**3.035**	**1.258**	**4.135**	**5.245**	**2.654**
Stem diameter (mm)	**6.846**	**8.303**	**8.734**	**9.465**	**6.470**	**7.653**	**2.098**	**8.946**
Leaf area (m)	**18.247**	**17.969**	**18.454**	**11.759**	**17.537**	**17.869**	**7.654**	**11.723**
Disc diameter (cm)	**9.009**	**12.519**	**13.406**	**20.972**	**8.183**	**11.982**	**11.988**	**20.419**
Seeds number disc^{-1}	**29.825**	**26.619**	**36.941**	**42.710**	**29.815**	**26.611**	**36.937**	**42.699**
Fertility percentage %	**10.038**	**5.125**	**4.964**	**7.220**	**9.942**	**3.042**	**4.750**	**6.011**
Dry plant weight(gm)	**21.390**	**10.994**	**15.926**	**23.626**	**21.370**	**10.965**	**15.916**	**23.619**
Yield per unit area (ton ha^{-1})	**25.416**	**12.341**	**21.980**	**32.073**	**24.359**	**12.247**	**21.881**	**31.995**

The ratio of genetic to environmental variance (σ^2g/σ^2e) and heritability in the broad sense ($h^2_{.b.s}$) at fertilizer levels of 0, 100, 200, and 300 (kg K ha^{-1}).

The results in Table 8 show that the ratio of genetic to environmental variance was greater than 1 for the traits whose genetic variance was higher than environmental. Its value ranged from 1.829 for the disc diameter trait at the 200 kg K ha^{-1} fertilizer level, to 5582.70 for the seed number disc^{-1} at the same fertilizer level. Consequently, the heritability in the broad sense was high for these traits, and at the four fertilizer levels it ranged from 0.693 for the fertility percentage trait at the 300 kg K ha^{-1} fertilizer level, to 0.999 for the seed number disc^{-1} at the four fertilizer levels and the total dry weight at the 100 and 200 kg K ha^{-1} fertilizer levels. For the traits of number of flowering days at a fertilizer level of 0 kg K ha^{-1}, fertility percentage at a fertilizer level of 100 kg K ha^{-1}, and stem diameter and leaf area at a fertilizer level of 200 kg K ha^{-1}, the genetic-to-environmental variance ratio was less than 1, reaching 0.75, 0.54, 0.061, and 0.139 for the four traits, respectively. This indicates that environmental variance constitutes the largest proportion of phenotypic variance. Consequently, broad-sense heritability was moderate for the trait of number of flowering days at a fertilizer level of 0 kg K ha^{-1} (0.429) and low for the other traits (0.352, 0.223, and 0.146 for the three traits, respectively). The heritability ratio indicates the confidence level at which the genotype can be distinguished from its phenotypic expression. The high heritability of these traits may be a result of additive gene action, and these traits are likely to respond to direct selection when desired. Improved, these results are consistent with Hassan (2016), who found differences in genetic parameters, including heritability, which was high for most traits, ranging between 63% for the traits of number of flowering days and number of seeds disc^{-1} and between 98% for the trait of total dry weight in the fall season. In the spring season, heritability ranged between 69% for the trait of number of disc seeds and between 97% for the traits of leaf area and total dry weight. They also agree with Hassan *et al.* (2019), who found that heritability was high, ranging between 63% and 95% for the traits of number of disc seeds and biological yield in the spring season and between 83% and 99% for the traits of 100-seed weight and disc area in the fall season.

Table 8. The ratio of genetic to environmental variance ($\sigma^2 g/\sigma^2 e$) and heritability in the broad sense (h^2.b.s) of the studied traits in sunflower at fertilizer levels of 0, 100, 200, 300 (kg K ha⁻¹) for the spring season of 2025.

Traits	σ^{2g}/σ^{2e}				h^2.b.s			
	0 kgkha^{-1}	100 kgkha^{-1}	200 kgkha^{-1}	300 kgkha^{-1}	0 kgkha^{-1}	100 kgkha^{-1}	200 kgkha^{-1}	300 kgkha^{-1}
Days to flowering (days)	0.75	8.18	12.417	3.25	0.429	0.891	0.925	0.765
Stem diameter (mm)	8.36	5.65	0.0612	8.38	0.893	0.850	0.223	0.893
Leaf area (m)	17.00	87.50	0.139	100.00	0.924	0.989	0.146	0.994
Disc diameter (cm)	4.71	10.90	1.829	18.22	0.825	0.916	0.800	0.948
Seeds number disc^{-1}	1392.35	1601.18	5582.70	1829.94	0.999	0.999	0.999	0.999
Fertility percentage %	51.03	0.54	20.571	2.26	0.981	0.352	0.954	0.693
Dry plant weight(gm)	522.25	187.50	802.303	2020.35	0.998	0.995	0.999	0.999
Yield per unit area (ton ha^{-1})	11.21	63.50	113.8	211.14	0.919	0.985	0.991	0.995

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