Genetic behavior for yield and its components in summer squash plant(*cucurbita pepo* L .) treated with amino acids - (casein hydrolysate)

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Abstract

This study, conducted in Nineveh province, Iraq, evaluated the heritability of certain growth and yield traits in four summer squash hybrids: Wissam F1, Private F1, Ha030 F1, and JAZ F1. The study **investigated** the effects of foliar spraying with amino acids - (casein hydrolysate) at five concentrations (0, 0.5, 1, 1.5, and 2 g/L) during the autumn growing season of 2025 at the Agricultural Research Field, College of Agriculture and Forestry, Mosul. The experiment consisted of twenty treatment combinations in a completely randomized block design (RCBD) with three replications. Analysis of variance (ANOVA) showed significant differences among the four hybrids in the mean squares for all studied traits except total leaf chlorophyll content and shoot dry matter percentage, where differences were non-significant. The Ha030 F1 hybrid exhibited the highest significant early fruit yield, while the JAZ F1 hybrid exhibited the highest total yield. The treatment with 2 g/L amino acids (casein hydrolysate) resulted in the highest early fruit yield, per-plant yield, total and marketable yields, significantly surpassing those of other hybrids. The highest early fruit yield was observed in hybrid Ha030 F1 plants treated with 2 g/L of amino acids (casein hydrolysate), while JAZ F1 plants treated with 2 g/L of amino acids (casein hydrolysate) exhibited the highest per plant yield, total and marketable fruit yield, significantly excelled on all other interaction treatments.

Genetic variance Components were significant for all studied traits except for total leaf chlorophyll content and the percentage of dry matter in the foliage. Environmental variance values were also significant for all traits. Broad-sense heritability was high for plant height, number of fruits per plant, per plant yield, total fruit yield, and marketable fruit yield. For fruit traits, a high heritability estimate indicates that the phenotypic performance of an individual is largely determined by its genetic constitution. This implies the potential for direct improvement of these traits through selection in subsequent growing seasons. The expected genetic advance, expressed as a percentage of the trait mean, ranged from low for total leaf chlorophyll content, foliage dry matter percentage, number of days to the appearance of the first female flower, and sex ratio, to moderate for the remaining traits.

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Keywords: Amino acids, summer squash, *Cucurbita pepo* L., heritability and genetic advance.

Introduction

Summer squash (*Cucurbita pepo* L.) is an important vegetable crop belonging to the Cucurbitaceae family. It is widely cultivated in Iraq for its tender fruits, which are rich in nutrients such as potassium, iron, phosphorus, copper, magnesium, manganese, and carbohydrates. It also contains a significant amount of vitamins, including vitamins B1 and B2 [13]. Furthermore, it has numerous medicinal uses [31].

The native habitat of summer squash is North America, where it was domesticated, particularly in Mexico and the southwestern United States [26]. It is cultivated in temperate climates worldwide. The United States and China are the largest producers of summer squash, followed by Russia and Ukraine, which are among the top four producers globally. According to the latest statistics, global summer squash production reached 14.8 million tons per hectare, with a cultivated area of 2.1 million hectares per hectare for the year 2025[9]. In Iraq, the cultivated area ranged between 140,000 and 160,000 dunams, concentrated in the province s of Nineveh, Baghdad, and Babylon. Total production reached 34,000 tons, according to the FAO report for 2025 [9].

Summer squash varieties and hybrids differ genetically in their vegetative, flowering, and fruiting patterns [20]. Hybrid summer squash plants also vary in yield per unit area, depending on their genetic potential and the environmental conditions during their growth and production. One economically acceptable production characteristic for consumers is the availability of high-yielding hybrids with high-quality fruit [16].

Plant breeders strive to find the best traits for consumers, they also conduct comparative studies of cultivated varieties and hybrids with the production factors of the country's conditions to select the best ones. Furthermore, choosing the appropriate variety and hybrid is one of the most important conditions for successful vegetable production, Consistent performance under different environmental conditions is crucial to determine the extent to which these varieties and hybrids adapt to the prevailing conditions of a particular region, as there are significant differences between them even within the same group or species [24].

Therefore, evaluating hybrids is a fundamental step in breeding programs, as it helps in selecting the best genetic combinations that can be adopted in commercial agriculture or used in subsequent breeding programs. Evaluating hybrids under different environmental conditions is essential to determine the extent of the hybrid’s stability and its ability to adapt to different climatic conditions, as the response of genetic combinations varies according to the environment in which they are grown. Therefore, studying the interaction between the genetic combination and the environment (G×E interaction) is one of the important foundations in selecting superior hybrids, because it helps in identifying hybrids that give the highest productivity and best quality traits under local agricultural conditions [8]. Furthermore, the evaluation of hybrids is not limited to yield alone, but also includes studying numerous morphological and quantitative traits such as plant height, number of female flowers, number of fruits per plant, fruit weight, and total yield, in addition to quality traits. These studies help identify genetically superior hybrids that can contribute to increased production and improved crop quality in line with consumer and market demands [28]

Foliar nutrition is an important method for supplying plants with primary and secondary nutrients, as well as various growth stimulants, which is reflected in increased vegetative growth, productivity, and improved quality. One type of foliar feeding is spraying with amino acids, which are carboxylic acids containing one or more amino groups. Amino acids are considered safe fertilizers for plants and crops, and they improve plant growth and nutrient absorption compared to chemical fertilizers. They also enhance soil vitality and its absorption of available nutrients, in addition to increasing stress resistance. This is achieved by promoting photosynthesis through increased chlorophyll production, which positively impacts yield, while reducing the toxic effects on plants resulting from the excessive use of chemical fertilizers of all types [27] Amino acids are bioactive compounds in plants, serving as indispensable intermediates in many metabolic pathways and building blocks for proteins. They contribute to the synthesis of numerous secondary compounds such as alkaloids, polyamines, and phenols [15].

The characteristics of any crop are determined by genetic and environmental interactions. Therefore, plant breeders should aim to understand the relationship between plant traits and metabolic processes, as well as phenotypic traits, since these are genetically controlled. This understanding can only be achieved by assessing genetic and phenotypic variations to develop a program for selecting multiple traits simultaneously [2]. Estimating the heritability of quantitative traits is one of the most important estimations that plant breeders have focused on. It has become clear that by estimating heritability in the broad sense, the contribution of both genetic and environmental influences to the trait's appearance can be determined. Thus, the heritability value can be a measure of the relationship between parents and offspring. Heritability is a crucial genetic parameter that must be known for any quantitative trait, as determining the best breeding method for improving a given trait depends on its estimation. Furthermore, its estimation is important for determining the expected genetic advance, which is the most significant application of quantitative heritability theory in plant breeding and improvement programs [5]

Therefore, the current study aims to the following :

1- Estimate heritability ratio, genetic and phenotypic variances and their coefficients, and the expected genetic advance of yield traits and their components for four summer squash hybrids under study.
2- Determine the best consternation of used amino acids (casein hydrolysate) in the study .

Materials and Methods

This study was conducted during the autumn growing season of 2025 at the Agricultural Research Field, College of Agriculture and Forestry, Mosul, located at latitude 36.35°N and longitude 43.15°E, at an altitude of 223 meters above sea level [10]. The aim was to estimate some genetic parameters of four summer squash hybrids: Wissam F1, Private F1, Ha030 F1, and JAZ F1, under the influence of casein hydrolysate foliar spraying at five concentrations (0, 0.5, 1, 1.5, and 2 g/L). The plants were sprayed with the four amino acid (casein hydrolysate) concentrations on three separate occasions: the first application was one week after transplanting to the permanent field, and the second and third applications were spaced 20 days apart. The seeds of the four hybrids were sown on August 25, 2025, indoors. The plastic sheet was used for the field of the Horticulture and Landscape Engineering Department. After the seedlings reached the 3-4 true leaf stage, they were transplanted to their permanent location on September 8, 2025. Planting was done in rows, represented by the experimental unit, which consisted of two rows, each 2 meters long and 0.75 meters wide, resulting in an area of 3 square meters for the experimental unit. The spacing between plants was 40 centimeters, with 5 plants per row, totaling 10 plants per experimental unit (30 plants per treatment). Drip irrigation pipes were then installed at the planting line level for each row. Agricultural management practices were carried out equally for all treatments [21].

Data were recorded for five randomly selected plants from each experimental

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unit. The data were statistically analyzed using SAS [32] software, and Duncan's multiple range test was used to compare means at a probability level of 0.05.

Phenotypic, genetic, and environmental variance, as well as the phenotypic and genetic coefficients of variation, were estimated according to [36] and other agencies).

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

Whereas:

(δ^2 P) Phenotypic variance

(δ^2G) Genotypic variance

δ^2E) Environmental variance(

$$\delta^2 G = (\delta^2 \text{ Cultivars} - \delta^2 E) / RB$$

$$\delta^2 E = Mse$$

Whereas:

Average of Cultivars squares= δ^2

Mean squared experimental error = δ^2 E

Mse = δ^2 E

Number of replicates = R

Amino acids-(casein hydrolysate) (5 = B)

$$PCV\ \% = (\sqrt{\delta^2 P} / \tilde{Y}) \times 100.$$

$$GCV\ \% = (\sqrt{\delta^2 G} / \tilde{Y}) \times 100.$$

Whereas:

(PCV) Phenotypic Coefficients of Variation

(GCV) Genotypic Coefficients of Variation

($\tilde{Y}$)It is the arithmetic mean of traits

H^2(b.s) Heritability broad sense [8] ,and according to the following equation:

$$H^2(b.s) = (\delta^2 G / \delta^2 P).$$

The importance of inheritance values, in the broad sense, was expressed according to the hierarchy shown by [4].

(Less than 40% is low, 40-60% is medium, and more than 60% is high).

The expected genetic advance (E.G.A.) was estimated based on the equation provided by [15] as follows.

$$E.G.A. = [(K\ H^2_{b.s.} \sqrt{\delta^2 P})]$$

Whereas:

Expected Genetic Advance (E.G.A)

K = 2.06 This is the intensity of selection for 5% of plants.

The expected genetic advance was estimated as a percentage of the arithmetic mean (% E.G.A.) as follows:

$$E.G.A.\ \% = [(K\ H^2(b.s) \sqrt{\delta^2 P}) / \tilde{Y}] \times 100.$$

The limits of expected genetic advance reported by [30] were adopted as follows:

Whereas:

Expected Genetic Advance (E.G.A)

K = 2.06 This is the intensity of selection for 5% of plants.

Results and Discussion

The results of the analysis of variance for the studied summer squash traits are shown in Table (1). The mean squares of the four hybrids were significant at a 1% probability level for all studied traits except for total leaf chlorophyll content and the percentage of dry matter in the vegetative growth, where the differences did not reach significance.

However, the mean squares of the amino acid treatments were significant at a 1% probability level for plant height, percentage of dry matter in vegetative growth, number of days to first female flower appearance, sex ratio, number of fruits per plant, early fruit yield, yield per plant, total fruit yield, and marketable fruit yield. The differences for total leaf chlorophyll content did not reach significance. The interaction between varieties and amino acids (casein hydrolysate) was significant at a 1% probability level for plant height, total leaf chlorophyll content, and percentage of dry matter in the vegetative growth. At a 5% probability level, it was significant for the number of days to first female flower appearance, sex ratio, early fruit yield, yield per plant, total fruit yield, and marketable fruit yield. Differences in the number of fruits per plant were not significant. This aligns with the findings of [11,18,22,25,23,35,36] who reported significant differences between varieties in growth and yield traits in summer squash.

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Table (1): Analysis of variance for the studied traits in summer squash, which represent the mean squares values.

SOV	Df	Mean Squares				
		Plant height (cm/plant^{-1})	**Total leaf chlorophyll content (mg/g^{-1} fresh weight)**	**Percentage of dry matter in the vegetative growth**	**Number of days to first female flower appearance (day/plant^{-1})**	**Sex ratio**
replicates	**2**	5.257	2197.771	0.846	0.494	0.005
Hybrids	**3**	826.159 **	30.618	3.090	9.602 **	0.051 **
Amino Acids (casein hydrolysate)	**4**	345.005 **	21.388	23.703 **	10.820 **	0.012 **
Hybrids × Amino Acids (casein hydrolysate)	**12**	148.283 **	63.713 **	6.658 **	2.020 *	0.002 *
Experimental Error	**38**	5.894	19.318	2.095	1.145	0.004

SOV	df	Mean Squares				
		Number of fruits per plant (fruits/plant^{-1})	**Early fruit yield (kg/ha^{-1})**	**Yield per plant (kg/plant^{-1})**	**Total fruit yield (to/ha^{-1})**	**Marketable fruit yield (to/ha^{-1})**
replicates	**2**	1.102	3254.699	28263.164	31.402	29.251
Hybrids	**3**	3.309 **	14301.833 **	95863.162 **	106.512 **	102.666 **

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Amino Acids(casein hydrolysate)	**4**	7.412 **	42355.161 **	226606.725 **	251.780 **	258.836 **
Hybrids × Amino Acids (casein hydrolysate)	**12**	0.055	738.143 *	1496.767 *	1.663 *	1.635 *
Experimental Error	**38**	0.134	680.183	3153.999	3.504	3.355

*** and ** are significant at probability levels of 0.05 and 0.01, respectively.**

Table (2) shows that there is a significant difference in height among the studied hybrids. The Wissam F1 hybrid significantly excelled on all other hybrids, achieving a height of (64.654 cm/plant^{-1}), compared to the Ha030 F1 hybrid, which produced the lowest plant height at (46.844 cm/plant^{-1}). Regarding the effect of amino acid spraying, plants treated with 2 g/L showed a significant increase in plant height compared to all other treatments, reaching (62.701 cm/plant^{-1}), while untreated plants produced the lowest height at (48.355 cm/plant^{-1}).

Regarding the interaction between hybrids and the effect of amino acid spraying, the 2 g/L^{-1} treatment for the JAZ F1 hybrid resulted in a significant increase in plant height (80.447 cm/plant^{-1}), significantly excelled on all other interaction cases. The untreated Ha030 F1 hybrid plants exhibited the lowest height value (38.057 cm/plant^{-1}).

Table (3) shows that the differences between the effects of hybrids and the amino acid spraying on total leaf chlorophyll content did not reach statistical significance. The interaction between amino acids and hybrids showed significant differences. Plants of the Ha030 F1 hybrid treated with 0.5 g/L^{-1} showed the highest total chlorophyll content in their leaves (36.433 mg/g^{-1} fresh weight), significantly excelled some other interaction treatments. Conversely, plants of the Private F1 hybrid treated with 1.5 g/L showed the lowest total chlorophyll content (23.087 mg/g^{-1} fresh weight).

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Table (2): Effect of hybrids, amino acid spraying, and their interaction on plant height (cm/plant^{-1}).

amino acid (g/L^{-1}) - (casein hydrolysate)	hybrids				Average effect of amino acid - (casein hydrolysate)
	Wissam F1	Private F1	Ha030 F1	JAZ F1	
0	58.833 d e	52.917 g h	38.057 j	43.613 i	48.355 d
0.5	63.443 c	62.500 c d	50.000 h	54.723 e – g	57.666 c
1	68.333 b	64.723 b c	51.333 g h	54.390 e – h	59.695 b
1.5	68.387 b	57.777 e f	42.833 i	58.057 e f	56.763 c
2	64.277 b c	54.083 f – h	52.000 g h	80.447 a	62.701 a
Average effect of hybrids	64.654 a	58.400 b	46.844 c	58.246 b	

*Means for factors sharing the same letter and their interaction do not differ significantly according to Duncan's multiple range test at a probability level of 0.05.

Table (3): Effect of hybrids, amino acid spraying, and their interaction on the total chlorophyll content of leaves (mg/g $^{-1}$ fresh weight).

amino acid (g/L^{-1}) - (casein hydrolysate)	hybrids				Average effect of amino acid- (casein hydrolysate)
	Wissam F1	Private F1	Ha030 F1	JAZ F1	
0	35.501 a	27.918 a-d	25.629 b-d	29.511 a-d	29.640 a
0.5	30.541 a-d	33.566 a b	36.433 a	28.680 a-d	32.305 a
1	32.532 a-c	35.313 a	31.742 a-c	28.619 a-d	32.051 a
1.5	31.066 a-d	23.087 d	35.459 a	31.309a-d	30.230 a
2	25.508 b-d	24.279 c d	32.166 a-c	36.125 a	29.519 a
Average effect of hybrids	31.029 a	28.832 a	32.286 a	30.849 a	

* Means for hybrids sharing the same letter for each factor and their interaction did not differ significantly according to Duncan's multiple range test at a probability level of 0.05.

Table (4) presents the results showing the effects of the studied hybrids on the percentage of dry matter in vegetative growth, with no significant differences recorded between them. However, the effect of amino acid spraying reached statistical significance, with the 1.5 g/L^{-1} treatment recording the highest percentage at (12.408%), significantly exceeding both the 0.5 g/L^{-1} treatment and the control treatment, which showed the lowest percentage at (9.450%).

Regarding the interaction between hybrids and amino acids, the differences reached statistical significance for the percentage of dry matter in vegetative growth, with Wissam F1 hybrid sprayed with 1.5 g/L^{-1} recording the highest percentage. The percentage of dry matter in vegetative growth reached (13.700%), significantly exceeding that of some other interaction treatments. The lowest percentage was recorded in the untreated and 0.5 g/L^{-1} JAZ F1 hybrids, at (7.967%) for each, respectively.

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Table (4): Effect of hybrids, amino acid spraying, and their interaction on the percentage of dry matter in vegetative growth.

amino acid (g/L^{-1}) - (casein hydrolysate)	Hybrids				Average effect of amino acid - (casein hydrolysate)
	Wissam F1	Private F1	Ha030 F1	JAZ F1	
0	8.733 e f	11.133 a-e	9.967 c-f	7.967 f	9.450 b
0.5	10.100 c-f	9.800 d-f	11.833 a-d	7.967 f	9.925 b
1	9.800 d-f	12.000 a-d	13.500 a b	13.533 a b	12.208 a
1.5	13.700 a	12.433 a-d	11.167 a-e	12.333 a-d	12.408 a
2	11.533 a-d	10.733 b-e	12.700 a-c	13.267 a b	12.058 a
Average effect of hybrids	10.773 a	11.220 a	11.833 a	11.013 a	

* Means for plants sharing the same letter for each factor and the interaction between them do not differ significantly according to Duncan's multiple range test at a probability level of 0.05.

Table (5) shows significant differences between the hybrids used in the number of days to the appearance of the first female flower. The Ha030 F1 hybrid exhibited early female flowering, requiring the fewest days to obtain the first female flower (40.720 days/plant^{-1}). This differed significantly from the Private F1 and Jaz F1 hybrids, which were delayed in flowering, requiring (41.853 days/plant^{-1}) and (42.346 days/plant^{-1}), respectively, to obtain the first female flower. Regarding the effect of foliar amino acid application, the number of days to the appearance of the first female flower reached the significance threshold for plants treated with a concentration of 0.5 g/L^{-1}. The 0.5 g/L^{-1} hybrid exhibited the earliest female flowering, occurring in 40,600 days/plant^{-1}. This significantly differed from plants treated with 1.5 g/L^{-1} and the control treatment, which had similar female flowering times of 41,566 days/plant^{-1} and (43,000 days/plant^{-1}), respectively.

Regarding the interaction between hybrids and amino acids, significant differences were observed. The Wissam F1 hybrid, treated with 0.5 g/L^{-1}, exhibited the earliest female flowering, reaching the shortest time to first female flower at (38,800 days/plant^{-1}), significantly excelled most other interaction treatments. Meanwhile, the untreated JAZ F1 hybrid achieved the highest average time at (44,333 days/plant^{-1}). Table (6) shows significant differences in sex ratio among the hybrids. The Wissam F1 hybrid exhibited the highest sex ratio at (0.900), significantly excelled the other hybrids, while the Private F1 hybrid had the lowest at 0.759. Regarding the effect of amino acid spraying, the differences reached statistical significance. Plants sprayed with 1.5 g/L^{-1} of amino acids showed the highest sex ratio at (0.856), significantly higher than unsprayed plants, which showed a sex ratio of (0.775). Concerning the interaction between the hybrids and the effect of amino acid spraying, the differences in sex ratio reached statistical significance. Plants of the Wissam F1 hybrid sprayed with 1.5 g/L showed the highest sex ratio. and 1 g/L^{-1} of amino acids resulted in the highest sex ratio (0.952), significantly excelled most other interaction treatments. In contrast, the unsprayed Private F1 hybrid plants exhibited the lowest sex ratio (0.697).

Table (5): Effect of hybrids, amino acid spraying, and their interaction on the number of days to first female flower appearance (days/plant^{-1}).

amino acid (g/L^{-1}) - (casein hydrolysate)	hybrids				Average effect of amino acid - (casein hydrolysate)
	Wissam F1	Private F1	Ha030 F1	JAZ F1	
0	41.933 b-e	43.733 a b	42.000 b-e	44.333 a	43.000 a
0.5	38.800 g	41.333 c-f	39.666 f g	42.600 a-c	40.600 c
1	41.666 c-f	41.200 c-f	40.133 e-g	40.333 d-g	40.833 b c
1.5	41.266 c-f	41.866 b-e	40.800 c-f	42.333 b-d	41.566 b
2	40.333 d-g	41.133 c-f	41.000 c-f	42.133 b-e	41.150 b c
Average effect of hybrids	40.800 b	41.853 a	40.720 b	42.346 a	

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*Means that share the same letter for each factor and their interaction do not differ significantly according to Duncan's multiple range test at a probability level of 0.05.

Table (6): Effect of hybrids, amino acid spraying, and their interaction on the sex ratio trait.

amino acid (g/L^{-1}) - (casein hydrolysate)	hybrids				Average effect of amino acid (casein hydrolysate)
	Wissam F1	Private F1	Ha030 F1	JAZ F1	
0	0.857 a-d	0.697 e	0.765 d e	0.782 d e	0.775 b
0.5	0.853 a-d	0.763 d e	0.843 a-d	0.834 b-d	0.823 a b
1	0.911 a-c	0.786 d e	0.754 d e	0.852 a-d	0.826 a b
1.5	0.952 a	0.799 c-e	0.837 b-d	0.838 b-d	0.856 a
2	0.928 a b	0.751 d e	0.858 a-d	0.860 a-d	0.849 a
Average effect of hybrids	0.900 a	0.759 c	0.811 b	0.833 b	

*Means for factors sharing the same letter and their interaction do not differ significantly according to Duncan's multiple range test at a probability level of 0.05.

Table (7) shows significant differences among the studied hybrids regarding the number of fruits per plant. The JAZ F1 hybrid plants achieved the highest number of fruits per plant (6.136 fruits/plant^{-1}), significantly excelled on all other hybrids, compared to the Ha030 F1 hybrid plants, which produced the lowest number of fruits per plant (5.006 fruits/plant^{-1}). The effect of amino acid spraying also reached significant levels. Plants treated with 2 g/L^{-1} produced the highest number of fruits per plant (6.558 fruits/plant^{-1}), significantly excelled all other treatments, compared to the untreated plants, which produced the lowest number of fruits per plant (4.495 fruits/plant^{-1}). Regarding the interaction between hybrids and the effect of amino acid spraying, the differences reached statistical significance. Plants of hybrid JAZ F1 sprayed with 2 g/L^{-1} of amino acids showed the highest number of fruits per plant (7.233 fruits/plant^{-1}), significantly excelled most other

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interaction treatments. Conversely, plants of hybrid Ha030 F1 not sprayed with amino acids showed the lowest number of fruits per plant (3.833 fruits/plant^{-1})

Table (7): Effect of hybrids, amino acid spraying, and their interaction on the number of fruits per plant (fruits/plant^{-1}).

amino acid (g/L^{-1}) - (casein hydrolysate)	hybrids				Average effect of amino acid - (casein hydrolysate)
	Wissam F1	Private F1	Ha030 F1	JAZ F1	
0	4.700 i j	4.566 j	3.833 k	4.883 h-j	4.495 d
0.5	5.266 f-j	5.200 g-j	4.766 h-j	5.866 d-g	5.275 c
1	5.366 f-i	5.200 g-j	5.033 h-j	6.066 c-e	5.416 c
1.5	6.166 b-d	5.933 d-f	5.466 e-h	6.633 a-c	6.050 b
2	6.766 a b	6.300 b-d	5.933 d-f	7.233 a	6.558 a
Average effect of hybrids	5.653 b	5.440 b	5.006 c	6.136 a	

* Means for factors sharing the same letter and interacting with each other do not differ significantly according to Duncan's multiple range test at a probability level of 0.05.

Table (8) indicates that the hybrids used differed significantly in early fruit yield. The Ha030 F1 hybrid produced an early fruit yield of (384.727 kg/ha^{-1}), significantly excelled all other hybrids compared to the hybrid that produced the lowest early fruit yield of (309.115 kg/ha^{-1}). Regarding the effect of amino acid spraying, the differences in early fruit yield reached statistical significance. Plants treated with 2 g/L^{-1} achieved the highest early fruit yield of (439.060 kg/ha^{-1}), significantly excelled all other treatments, compared to plants not treated with amino acids, which produced the lowest early fruit yield of (285.71 kg/ha^{-1}). Regarding the interaction between the effects of hybrids and amino acid spraying, the differences reached statistical significance. Plants of hybrid Ha030 F1 treated with 2 g/L^{-1} of amino acids exhibited the highest early yield (507.840 kg/ha^{-1}), significantly excelled all other interaction treatments, compared to the untreated hybrid JAZ

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F1, which yielded the lowest early yield (256.050 kg/ha^{-1}).

Tables (9) and (10) illustrate the significant differences between the hybrids in yield per plant and total fruit yield. The JAZ F1 hybrid plants exhibited the highest yield per plant and total fruit yield, reaching (992.180 kg/plant^{-1}) and (33.072 ton/ha^{-1}), significantly excelled on all other hybrids. This contrasts with the Ha030 F1 hybrid plants, which yielded the lowest yield per plant and total fruit yield, at (0806.55 kg/plant^{-1}) and (26.884 ton/ha^{-1}). Regarding the effect of amino acid spraying, significant differences were observed in both yield per plant and total fruit yield, with plants treated with 2 g/L^{-1} exhibiting the most pronounced results. The treatment with 2 g/L^{-1} resulted in the highest yield per plant and total fruit yield, reaching respectively (1057.840 kg/plant^{-1}) and (35.261 ton/ha^{-1}), significantly surpassing all other treatments. The lowest yield per plant and total yield were recorded in untreated plants, at (693.540 kg/plant^{-1}) and (23.117 ton/ha^{-1}) respectively. The differences reached statistical significance in terms of the interaction between the hybrids and the amino acid spray on yield per plant, with JAZ F1 hybrid plants treated with 2 g/L^{-1} exhibiting the highest yield per plant, with a total yield of (1172.53 kg/plant^{-1}) and (39.084 ton/ha^{-1}), significantly excelled all other interaction treatments. Conversely, untreated hybrid Ha030 F1 plants yielded the lowest yield per plant, with a total yield of (595.780 kg/plant^{-1}) and (19.859 ton/ha^{-1})

Table (8): Effect of hybrids, amino acid spraying, and their interaction on the early fruit yield (kg/ha^{-1}).

amino acid (g/L^{-1}) - (casein hydrolysate)	hybrids				Average effect of amino acid - (casein hydrolysate)
	Wissam F1	Private F1	Ha030 F1	JAZ F1	
0	278.240 j k	298.980 h-k	309.560 g-j	256.050 k	285.710 c
0.5	367.040 d-f	365.970 d-f	396.190 b-d	312.490 g-j	360.420 b
1	355.410 d-g	328.410 f-i	369.170 d-f	306.690 g-j	339.920 b
1.5	306.700 g-j	295.450 h-k	340.870 e-h	282.030 i-k	306.260 c
2	419.570 b c	440.520 b	507.840 a	388.300 c-e	439.060 a

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Average effect of hybrids	345.393 b	345.865 b	384.727 a	309.115 c

*Means for all factors sharing the same letter and their interaction do not differ significantly according to Duncan's multiple range test at a probability level of 0.05.

Table (9): Effect of hybrids, amino acid spraying, and their interaction on the trait of yield per plant (kg/plant^{-1}).

amino acid (g/L^{-1}) - (casein hydrolysate)	hybrids				Average effect of amino acid - (casein hydrolysate)
	Wissam F1	Private F1	Ha030 F1	JAZ F1	
0	715.630 i j	685.070 j k	595.780 k	777.680 g-j	693.540 d
0.5	819.070 g-i	799.340 g-i	759.930 h-j	962.940 c-e	835.320 c
1	844.930 f-h	809.170 g-i	822.430 g h	984.030 b-e	865.140 c
1.5	979.970 b-e	927.170 d-f	883.100 e-g	1063.730 b c	963.490 b
2	1079.100 b	1008.230 b-d	971.500 d-e	1172.530 a	1057.840 a
Average effect of hybrids	887.740 b	845.790 c	806.550 c	992.180 a	

*Means for all factors sharing the same letter and their interaction do not differ significantly according to Duncan's multiple range test at a probability level of 0.05.

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Table (10): Effect of hybrids, amino acid spraying, and their interaction on total fruit yield (tons/ha^{-1}).

amino acid (g/L^{-1}) - (casein hydrolysate)	hybrids				Average effect of amino acid - (casein hydrolysate)
	Wissam F1	Private F1	Ha030 F1	JAZ F1	
0	23.854 i j	22.835 j k	19.859 k	25.923 g-j	23.117 d
0.5	27.302 g-i	26.644 g-i	25.331 h-j	32.098 c-e	27.843 c
1	28.164 f-h	26.972 g-i	27.414 g h	32.801 b-e	28.837 c
1.5	32.665 b-e	30.905 d-f	29.436 e-g	35.457 b c	32.116 b
2	35.970 b	33.607 b-d	32.383 c-e	39.084 a	35.261 a
Average effect of hybrids	29.591 b	28.192 c	26.884 c	33.072 a	

* Means for all factors sharing the same letter and their interaction do not differ significantly according to Duncan's multiple range test at a probability level of 0.05.

Table (11) shows that there are significant differences between hybrids in the marketable fruit yield, as the JAZ F1 hybrid gave the highest yield with a weight of (32.541 ton/ha^{-1}) and significantly superior to the other hybrids, compared to the lowest yield recorded for the Ha030 F1 hybrid with a weight of (26.466 ton/ha^{-1}). Regarding the effect of spraying with amino acids, the differences reached the level of significance for the marketable fruit yield, as the plants treated with 2 g/L^{-1} of amino acids gave the highest marketable yield with a weight of (34.886 ton/ha^{-1}) and significantly excelled on all other treatments, compared to the plants not treated with amino acids, which gave the lowest yield with a weight of (22.577 ton/ha^{-1}). In connection with the previous two points regarding the interaction between hybrids and amino acid spraying, the differences in marketable fruit yield reached statistical significance. The JAZ F1 hybrid, sprayed with 2 g/L^{-1}, produced the highest yield (38.669 ton/ha^{-1}), significantly excelled all other interaction treatments. This was in contrast to the lowest yield achieved by

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the unsprayed Ha030 F1 hybrid (19.399 ton/ha^{-1}).

Table 11: Effect of hybrids, amino acid spraying, and their interaction on marketable fruit yield (t/ha^{-1}).

amino acid (g/L^{-1}) - (casein hydrolysate)	hybrids				Average effect of amino acid - (casein hydrolysate)
	Wissam F1	Private F1	Ha030 F1	JAZ F1	
0	23.302 i j	22.306 j k	19.399 k	25.303 h-j	22.577 d
0.5	26.762 g h	26.144 g-i	24.867 h-j	31.499 d e	27.317 c
1	27.679 f-h	26.541 g-i	26.972 g h	32.267 c-e	28.364 c
1.5	32.189 c-e	30.500 d-f	29.047 e-g	34.968 b c	31.676 b
2	35.582 b	33.245 b-d	32.047 c-e	38.669 a	34.886 a
Average effect of hybrids	29.103 b	27.747 c	26.466 c	32.541 a	

* Means that share the same letter for each factor and whose interaction does not differ significantly from one another according to Duncan's multiple range test at a probability level of 0.05.

Means that share the same letter for each factor and whose interaction does not differ significantly from one another according to Duncan's multiple range test at a probability level of 0.05. Table (12) shows the values of the components of phenotypic variance (genetic and environmental) and the genetic parameters (genetic and phenotypic coefficients of variation, broad-sense heritability, expected genetic advance, and expected genetic advance as a percentage) for the traits under study in zucchini squash. It is evident that the values of genetic variance were significant above zero for all the traits under study except for the traits of total leaf chlorophyll content and the percentage of dry matter in vegetative growth. Meanwhile, the values of environmental variance were significant above zero for all the traits.

These results are consistent with those obtained by [1,7,14,18, 23,22,38] regarding the significant values of genetic and environmental variance for some of the traits. These results are consistent with the previous studies of squash.

Table (12): Overall mean and components of phenotypic variance (genetic and environmental) and genetic parameters for the studied traits in summer squash.

Genetic parameter	studied traits				
	Plant height (cm/plant^{-1})	Total leaf chlorophyll content (mg/g^{-1} fresh weight)	Percentage of dry matter in the vegetative growth	Number of days to first female flower appearance (day/plant^{-1})	Sex ratio
Genetic variance	54.684 39.749±	0.753 1.593±	0.066 0.162±	0.563 0.463±	0.003 0.001±
Environmental variance	5.894 2.227±	19.318 7.301±	2.095 0.791±	1.145 0.432±	0.004 0.002±
phenotypic variance	60.578	20.071	2.161	1.708	0.007
Coefficient of genetic variation	12.965	2.822	2.291	1.811	6.631
phenotypic coefficient	13.646	14.569	13.114	3.154	10.129
Broad-sense heritability	0.902	0.037	0.030	0.329	0.428
Expected genetic advance	14.462	0.341	0.091	0.886	0.074
Expected genetic advance as a	25.356	1.109	0.812	2.139	8.958

percentage					
Overall average of the trait	**57.036**	**30.749**	**11.210**	**41.430**	**0.826**
Genetic parameter	studied traits				
	Number of fruits per plant (fruits/plant $^{-1}$)	**Early fruit yield (kg/ha $^{-1}$)**	**Yield per plant (kg/plant $^{-1}$)**	**Total fruit yield (ton/ha $^{-1}$)**	**Marketable fruit yield (ton/ha $^{-1}$)**
Genetic variance	0.211 0.159±	908.110 688.430±	6180.611 4613.288±	6.867 5.125±	6.620 4.940±
Environmental variance	0.134 0.050±	680.183 257.085±	3153.999 1192.100±	3.504 1.324±	3.355 1.268±
phenotypic variance	0.345	1588.293	9334.610	10.371	9.975
Coefficient of genetic variation	8.263	8.702	8.902	8.902	8.883
phenotypic coefficient	10.566	11.509	10.941	10.940	10.904
Broad-sense heritability	0.612	0.571	0.662	0.662	0.664
Expected genetic advance	0.741	46.878	131.757	4.392	4.320
Expected genetic advance as a percentage	13.330	13.538	14.920	14.921	14.915
Overall average of the	**5.559**	**346.275**	**883.067**	**29.435**	**28.965**

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trait					

The results indicate that the values of genetic variance were higher than the values of environmental variance for plant height, number of fruits per plant, early fruit yield, yield per plant, total fruit yield, and marketable fruit yield, and lower than for all other traits.

The highest values for the genetic variation coefficient were recorded for plant height (12.965), while the highest values for the phenotypic variation coefficient were recorded for plant height (13.646), total leaf chlorophyll content (14.569), percentage of dry matter in vegetative growth (13.114), and early fruit yield (11.509). This aligns with the findings of [12,14,19,22,31,33,34] who reported varying values for the genetic and phenotypic variation coefficients of variation in zucchini squash.

It was found that the values of the phenotypic variation coefficient were significantly higher than the values of the genetic variation coefficient for all traits. This indicates the influence of the environmental factor, specifically the amino acid spray treatments, on the studied traits to varying degrees. This is because most of these traits are quantitative, and therefore selection is effective for these traits based on their phenotypic characteristics [6].

Broad-sense heritability values ranged from 0.030 for the percentage of dry matter in vegetative growth to 0.902 for plant height. These values were high for plant height (0.902), number of fruits per plant (0.612), yield per plant (0.662), total fruit yield (0.662), and marketable fruit yield (0.664). They were moderate for sex ratio (0.428) and early fruit yield (0.571), and low for the remaining traits. Previous studies have yielded varying broad-sense heritability values for some traits in zucchini squash, including , [1,3,7,12,14,19,22,23,31,33,34,38] A high heritability of any trait provides breeders with a good opportunity to improve that trait through direct selection [5] Table (12) also indicates that the expected genetic advance values as a percentage of the average trait ranged from low for the traits of total leaf chlorophyll content (1.109), percentage of dry matter in vegetative growth (0.812), number of days to the appearance of the first female flower (2.139), and sex ratio (8.958), to moderate for the remaining traits. [12,14,18,22,32,33,38] and all indicated that the genetic advance values varied for the studied traits in the zucchini squash plant. The relationship between genetic parameters (genetic variation coefficients, phenotypic variation, heritability, and expected genetic advance as a percentage) indicates that their values were consistent, either increasing or decreasing for most of the traits under study. This demonstrates a strong correlation between them. Therefore, based on this strong correlation, the expected genetic advance in future selection cycles can be predicted using the values of the phenotypic variation

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coefficient. In such cases, mass selection can achieve the desired goals for crop improvement [36].

The relationship between genetic parameters (genetic variation coefficients, phenotypic variation, heritability, and expected genetic advance as a percentage) indicates that their values were consistent, either increasing or decreasing for most of the traits under study. This demonstrates a strong correlation between them. Therefore, based on this strong correlation, the expected genetic advance in future selection cycles can be predicted using the values of the phenotypic variation coefficient. In such cases, mass selection can achieve the desired goals for crop improvement [37].

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