



Phenotypic Variance Analysis of Five Gynoeceous Cucumber Hybrids under the Effect of Spraying with Nano Zinc

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10.18805/ag.DF-871

ABSTRACT

Background: This study aimed to evaluate the performance of five gynoeceous cucumber hybrids under foliar spraying with nano zinc oxide during the 2025-2026 agricultural season in an unheated plastic house.

Methods: Five gynoeceous cucumber hybrids were tested under foliar application of nano zinc oxide. The studied traits included number of leaves, leaf zinc content, fruit set percentage, plant yield and fruit weight. Genetic parameters were estimated to determine genetic and environmental variance and broad-sense heritability values.

Result: The results indicated significant genetic variance among the studied hybrids. The single hybrid V1 excelled in most traits, recording 32.11 leaves plant⁻¹, 164.64 mg kg⁻¹ leaf zinc content, 67.71% fruit set, 3.497 kg plant⁻¹ yield and 83.546 g fruit weight compared with the other hybrids. Genetic variance exceeded environmental variance in number of leaves, fruit set percentage and plant yield, with high broad-sense heritability values (0.8991, 0.9464 and 0.9003), indicating the possibility of achieving tangible genetic progress. Foliar spraying with nano zinc oxide at 100 mg L⁻¹ significantly improved most traits compared with the control. The interaction between hybrids and nano zinc was significant for leaf zinc content and fruit set percentage, where V1 at 100 mg L⁻¹ recorded the highest values (269.60 mg kg⁻¹ and 73.82%), while V4 at 0 mg L⁻¹ recorded the lowest values (67.87 mg kg⁻¹ and 57.06%).

Key words: Broad-sense heritability, Genetic variance, Gynoeceous cucumber hybrids, Nano zinc oxide, Protected agriculture, Yield components.

INTRODUCTION

Cucumber (*Cucumis sativus* L.) is one of the most important vegetable crops belonging to the family Cucurbitaceae and is widely cultivated under different agricultural systems. The crop has considerable nutritional value due to its high water content and the presence of essential minerals and vitamins. In addition, cucumber is widely grown under protected cultivation conditions because of its rapid growth, early production and high market demand (Naureen *et al.*, 2022).

Phenotypic variance analysis is an important approach for evaluating the performance of different genotypes, as it enables the estimation of genetic and environmental variance and their relative contributions (Mohammadi *et al.*, 2025). It also facilitates the study of genotype × environment interactions and helps in identifying stable and superior genotypes under different conditions. Furthermore, this analysis improves the efficiency of selection programs through the estimation of heritability and expected genetic advance (Shukla *et al.*, 2025). In addition, genetic variability and divergence among cucumber genotypes are essential for successful breeding programs, as the presence of sufficient genetic diversity enables the selection of superior parents and improves yield and quality traits (Usha *et al.*, 2025).

Cucumber hybrids, particularly single hybrids, are among the essential requirements in protected agriculture due to their uniformity, vigor, fruit quality and stable performance under different environmental conditions (Poonia *et al.*, 2024). Triple hybrids also contribute to improving growth and production in protected cultivation

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How to cite this article: Abdullah, A.N. and Alabdaly, M.M.M. (2026). Phenotypic Variance Analysis of Five Gynoeceous Cucumber Hybrids under the Effect of Spraying with Nano Zinc. *Agricultural Science Digest*. **46(5)**: 786-791. doi: 10.18805/ag.DF-871.

Submitted: 03-03-2026 **Accepted:** 25-04-2026 **Online:** 06-05-2026

systems by exploiting their broader genetic base and diversity (Al-Tamiri *et al.*, 2022).

The cucumber growing season in Iraq under protected agriculture is characterized by its short duration, which necessitates adopting efficient nutritional programs that meet the plant's requirements within a limited time period. The use of nutrients in nano form is considered a suitable option due to their higher absorption efficiency and reduced fertilizer quantities compared with conventional fertilizers (Hasan, 2024; Alabdaly and Abdullah, 2024).

Nano zinc oxide (ZnO-NPs) is considered an important nutrient in foliar application under protected cultivation due to its higher efficiency compared with conventional zinc sources. Its small particle size and large surface area enhance absorption and translocation within plant tissues. Zinc plays a key role in enzyme activation, chlorophyll

synthesis and improving photosynthetic efficiency, which positively affects plant growth and productivity (Gupta *et al.*, 2022; Xu *et al.*, 2022).

Therefore, this study aimed to estimate genetic parameters, including genetic and environmental variance, heritability and expected genetic advance, in order to identify the best-performing cucumber hybrids and the traits most responsive to nano zinc application, as well as to evaluate their potential use in breeding and improvement programs under protected cultivation conditions.

MATERIALS AND METHODS

The experiment was conducted during the fall growing season of 2025 at the experimental fields of the College of Agriculture, University of Anbar, located in the city of Ramadi (33.4263°N, 43.3332°E), inside an unheated plastic house. The environmental conditions inside the plastic house, including temperature and relative humidity, were monitored throughout the growing season and remained within suitable ranges for cucumber growth. The plastic house was prepared by carrying out all service operations followed in protected cultivation and organic and chemical fertilizers were added according to the recommendations of Mohammed *et al.* (2021), with the implementation of a preventive program for insect and fungal control as needed. The plastic house was divided into five beds measuring 80 cm in width and 42 m in length, with spaces left between the beds. It was further divided into 45 experimental units with a length of 2.80 m. Seedlings were planted in two rows per bed at a spacing of 40 cm between plants, with 14 plants per experimental unit. Each treatment was replicated three times and data were recorded from five randomly selected plants within each experimental unit to ensure accuracy and reduce experimental error.

Seeds of five locally produced female cucumber hybrids were planted, including three single and two triple hybrids. After the appearance of the second true leaf, the seedlings were transferred to the plastic house and all recommended agricultural practices in protected cultivation were carried out. The study included two factors: five female cucumber hybrids and nano zinc oxide (ZnO-NPs), which was sprayed at three levels (0, 50 and 100 mg L⁻¹). These concentrations were selected based on previous studies that reported their effectiveness in improving plant growth and yield under protected cultivation conditions. Plants were sprayed three times: the first before flowering, the second ten days after the first and the third ten days after the second spray according to Hussein and Khalaf (2022). The experiment was conducted as a factorial experiment arranged as split plots within a randomized complete block design (RCBD) with three replicates, where nano zinc oxide spray levels were assigned to the main plots, while hybrids were assigned to the subplots. After data collection, the data were statistically analyzed using GenStat software. The analysis of variance (ANOVA) was performed according to the experimental design to determine the significance of treatments and means were compared using the least

significant difference (L.S.D.) test at the 5% probability level. After the appearance of significant differences for the studied traits, genetic analysis was conducted and the required genetic parameters were estimated.

Studied traits

Vegetative growth and chemical traits included:

1. Number of leaves per plant.
2. Zinc content in leaves (mg kg⁻¹ dry matter): Determined using an Atomic Absorption Spectrophotometer (AAS) according to the method described by David (1958).

Flowering and yield traits included:

1. Fruit set percentage (%):

$$\frac{\text{Number of fruits}}{\text{Total number of flowers}} \times 100$$

2. Fruit weight (g):

$$\frac{\text{Yield of the experimental unit}}{\text{Number of fruits in the experimental unit}}$$

3. Plant yield (kg plant⁻¹):

$$\frac{\text{Productivity of each experimental unit}}{\text{The number of plants}}$$

Genetic parameters

Genetic analysis was performed based on the expected mean squares (EMS). Genetic variance (σ^2g), environmental variance (σ^2e) and phenotypic variance (σ^2p) were calculated. Broad-sense heritability (H^2bs), genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were estimated, in addition to calculating the expected genetic advance (GA) for the studied traits. Genetic, phenotypic and environmental variances were estimated according to the equations reported by Singh and Choudhary (2007) as follows:

Genetic variance:

$$\sigma^2g = \frac{MSg - MSe}{r}$$

Environmental variance:

$$\sigma^2e = MSe$$

Phenotypic variance:

$$\sigma^2p = \sigma^2g + \sigma^2e$$

Broad-sense heritability:

$$H^2bs = \frac{\sigma^2g}{\sigma^2p} \times \frac{100}{100}$$

Genotypic coefficient of variation:

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

Phenotypic coefficient of variation:

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

Expected genetic advance:

$$GA = k \times \sqrt{(\sigma^2p)} \times H^2bs$$

RESULTS AND DISCUSSION

Vegetative growth and chemical traits

The results presented in Table 1 and 2 showed significant differences among the studied gynoecious hybrids in number of leaves and leaf zinc content. The single hybrid V1 recorded the highest values, whereas the hybrid V4 recorded the lowest values. Spraying with nano zinc oxide at 100 mg L⁻¹ significantly improved the number of leaves and leaf zinc content compared with the control treatment. The interaction did not show a significant effect on number of leaves, whereas it was significant for leaf zinc content, where V1Zn100 recorded the highest value and V4Zn0

recorded the lowest value. Regarding genetic parameters, the results showed that genetic variance exceeded environmental variance in both traits (Al-Khazarji and Alabdaly, 2025).

This superiority is attributed to the genetic advantage and higher physiological efficiency of the single hybrid, which enhances vegetative growth and nutrient accumulation, in agreement with Altamari *et al.* (2019) and Mohammed and Alabdaly (2023). This effect is attributed to the role of zinc in enzyme activation, chlorophyll synthesis and improving photosynthesis efficiency, as well as enhanced nutrient absorption and translocation, in agreement with Abdelkhalik *et al.* (2025) and Valdez-Aguilar *et al.* (2025). This may be due to its involvement in auxin (IAA) synthesis and regulation of cell division and expansion (Gao *et al.*, 2024). This may be attributed to the

Table 1: Genetic parameters for the number of leaves trait in five gynoecious cucumber hybrids under the effect of foliar spraying with nano zinc.

Nano zinc concentrations (mg L ⁻¹)	V1	V2	V3	V4	V5	Mean
Zn0	29.60	27.33	28.47	26.27	26.73	27.68
Zn50	31.20	29.60	30.07	27.47	28.07	29.28
Zn100	35.53	31.73	34.00	29.80	30.27	32.27
Mean (V)	32.11	29.56	30.84	27.84	28.36	-
LSD 0.05	Hybrids		Concentrations		Interaction	
	0.98		1.97		N.S	
Genetic parameters						
Genetic variance (σ ² g)	Environmental variance (σ ² e)	Phenotypic variance (σ ² p)	Broad-sense heritability (H ²)	Genotypic coefficient of variation (GCV)	Phenotypic coefficient of variation (PCV)	Expected genetic advance (GA)
8.9543	1.0050	9.9593	0.8991	0.1006	0.1061	5.8507

Table 2: Genetic parameters for the leaf zinc content in five gynoecious cucumber hybrids under the effect of foliar spraying with nano zinc.

Nano zinc concentrations (mg L ⁻¹)	V1	V2	V3	V4	V5	Mean
Zn0	96.57	76.23	83.07	67.87	71.67	79.08
Zn50	127.77	118.67	125.07	108.07	111.63	118.24
Zn100	269.60	215.40	221.47	127.40	136.20	194.01
Mean (V)	164.64	136.77	143.20	101.11	106.50	-
LSD 0.05	Hybrids 1.791		Concentrations 5.413		Interaction 5.417	
Genetic parameters						
Genetic variance (σ ² g)	Environmental variance (σ ² e)	Phenotypic variance (σ ² p)	Broad-sense heritability (H ²)	Genotypic coefficient of variation (GCV)	Phenotypic coefficient of variation (PCV)	Expected genetic advance (GA)
2103.4427	3.3870	2106.8297	0.9984	0.3516	0.3519	94.4941

interaction between genetic superiority and responsiveness to nano zinc application, which improves nutrient uptake and accumulation, in agreement with Muhemed and Mijwel (2020). High heritability values and close genotypic and phenotypic coefficients of variation indicate low environmental influence and the possibility of achieving genetic improvement through selection. These results are in agreement with Yadav *et al.* (2024); Pushpalatha *et al.* (2016) and Tackal *et al.* (2024). This is also supported by Thakur *et al.* (2023). This reflects the effectiveness of selection based on these traits in cucumber breeding programs.

Flowering and yield traits

The results presented in Table 3, 4 and 5 showed significant differences among the studied gynoeccious hybrids in fruit set percentage, fruit weight and plant yield. The single hybrid V1 recorded the highest values, whereas the hybrid V4 recorded the lowest values. Spraying with nano zinc oxide

at 100 mg L⁻¹ significantly improved fruit set percentage, fruit weight and plant yield compared with the control treatment. The interaction showed a significant effect on fruit set percentage, where V1Zn100 recorded the highest value, whereas V4Zn0 recorded the lowest value. However, the interaction did not show a significant effect on fruit weight and plant yield. Regarding genetic parameters, the results indicated that genetic variance exceeded environmental variance in the studied traits.

This superiority is attributed to the high genetic efficiency of the single hybrid in regulating reproductive processes and achieving a better balance between vegetative and reproductive growth, in addition to enhancing photosynthetic efficiency and carbohydrate accumulation, which are effectively directed toward reproductive organs, in agreement with Poonia *et al.* (2024) and Subedi *et al.* (2024). This effect is attributed to the physiological role of zinc in activating enzymes associated with fertilization

Table 3: Genetic parameters for the fruit set percentage (%) in five gynoeccious cucumber hybrids under the effect of foliar spraying with nano zinc.

Nano zinc concentrations (mg L ⁻¹)	V1	V2	V3	V4	V5	Mean
Zn0	64.67	62.44	63.16	57.06	59.48	61.36
Zn50	64.64	62.06	61.64	59.65	59.45	61.49
Zn100	73.82	66.42	67.83	58.09	62.16	65.66
Mean (V)	67.71	63.64	64.21	58.27	60.36	-
LSD 0.05	Hybrids		Concentrations		Interaction	
	1.45		1.26		2.41	
Genetic parameters						
Genetic variance (σ ² g)	Environmental variance (σ ² e)	Phenotypic variance (σ ² p)	Broad-sense heritability (H ²)	Genotypic coefficient of variation (GCV)	Phenotypic coefficient of variation (PCV)	Expected genetic advance (GA)
39.1877	2.2180	41.4057	0.9464	0.0996	0.1024	12.5576

Table 4: Genetic parameters for the fruit weight (g) in five gynoeccious cucumber hybrids under the effect of foliar spraying with nano zinc.

Nano zinc concentrations (mg L ⁻¹)	V1	V2	V3	V4	V5	Mean
Zn0	81.700	79.473	80.790	78.707	78.963	79.927
Zn50	83.840	82.560	83.123	81.557	81.853	82.587
Zn100	85.097	84.580	85.570	82.857	83.770	84.375
Mean (V)	83.546	82.204	83.161	81.040	81.529	-
LSD 0.05	Hybrids 0.583		Concentrations 2.688		Interaction N.S	
Genetic parameters						
Genetic variance (σ ² g)	Environmental variance (σ ² e)	Phenotypic variance (σ ² p)	Broad-sense heritability (H ²)	Genotypic coefficient of variation (GCV)	Phenotypic coefficient of variation (PCV)	Expected genetic advance (GA)
3.2435	0.3590	3.6025	0.9003	0.0219	0.0231	3.5237

Table 5: Genetic parameters for the plant yield (kg plant⁻¹) in five gynococious cucumber hybrids under the effect of foliar spraying with nano zinc.

Nano zinc concentrations (mg L ⁻¹)	V1	V2	V3	V4	V5	Mean
Zn0	3.317	3.046	3.190	2.684	2.832	3.014
Zn50	3.409	3.210	3.231	2.961	2.996	3.162
Zn100	3.765	3.571	3.317	3.025	3.202	3.376
Mean (V)	3.497	3.276	3.246	2.890	3.010	-
LSD 0.05	Hybrids 0.238		Concentrations 0.1078		Interaction N.S	
Genetic parameters						
Genetic variance (σ²g)	Environmental variance (σ²e)	Phenotypic variance (σ²p)	Broad-sense heritability (H²)	Genotypic coefficient of variation (GCV)	Phenotypic coefficient of variation (PCV)	Expected genetic advance (GA)
0.1503	0.0596	0.2099	0.7161	0.1218	0.1439	0.6764

processes, pollen formation and pollen tube growth. In addition, zinc improves photosynthetic efficiency and enhances assimilate translocation from source to sink, which reduces flower and young fruit drop. These findings are consistent with Lavanya *et al.* (2024) and Gupta *et al.* (2022). Furthermore, zinc contributes to hormonal regulation, particularly auxin synthesis, which promotes cell division and expansion, leading to improved fruit development and increased yield (Tripathi *et al.*, 2025). However, the interaction did not show a significant effect on fruit weight and plant yield, indicating greater stability of these traits and lower influence of factor interaction. High heritability values and close genotypic and phenotypic coefficients of variation indicate low environmental influence and the possibility of achieving genetic improvement through selection, in agreement with Pooja *et al.* (2019); Tadkal *et al.* (2024) and Bhati *et al.* (2023).

CONCLUSION

The single hybrid V1 showed superior performance in most studied traits compared with the other hybrids, reflecting its high physiological and genetic efficiency under protected cultivation conditions. Foliar spraying with nano zinc oxide, particularly at 100 mg L⁻¹, significantly improved vegetative growth and yield traits, confirming its effectiveness in enhancing plant productivity. The predominance of genetic variance over environmental variance, along with high heritability values and close genotypic and phenotypic coefficients of variation, indicates strong genetic control and limited environmental influence. The estimated genetic advance further suggests the possibility of achieving tangible genetic progress through the adoption of these traits in future cucumber breeding and improvement programs. Therefore, the use of hybrid V1 and foliar nano zinc application at 100 mg L⁻¹ is recommended under protected cultivation conditions.

Conflict of interest

On behalf of all authors, we confirm that there are no conflicts of interest regarding this manuscript.

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