Journal of Medicinal and Industrial Plant Sciences (2025) 3 (4): 1- 12
ISSN (P): 2959 – 121X
ISSN (E): 3106 – 5406
DOI: https://doi.org/10.32894/MEDIP.25.3.4.1

The response of some varieties of soybean *Glycine max* L. to spraying ascorbic acid on the characteristics and components of yield

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ABSTRACT

The study was conducted at the Research Station of the Field Crops Department, College of Agriculture, Tikrit University, during the summer season of 2024, with the aim of evaluating the effect of foliar application of ascorbic acid on the growth and yield of three soybean cultivars (Shaimaa, Lee, Laura) using four concentrations (0, 50, 100, 150 mg L^{-1}). The experiment was laid out in a randomized complete block design (RCBD) under a split-plot arrangement with three replications. The results revealed that foliar spraying with 150 mg L^{-1} of ascorbic acid significantly enhanced several traits, including plant height (54.06 cm), leaf area (1982.99 cm^2 plant $^{-1}$), number of pods (134.23 pods plant^{-1}), 500-seed weight (68.44 g), and total yield (2.30 t ha^{-1}). Among the cultivars, “Shaimaa” outperformed the others in terms of leaf area (2006.66 cm^2 plant^{-1}), number of pods (133.62 pods plant^{-1}), 500-seed weight (67.46 g), and recorded the highest total yield (2.30 t ha^{-1}). Moreover, the interaction between cultivars and ascorbic acid concentrations had a significant effect, as the combination (Shaimaa × 150 mg L^{-1}) produced the highest total yield (2.48 t ha^{-1}), while the combination (Lee × 0 mg L^{-1}) recorded the lowest values for several traits. These findings indicate the efficiency of foliar application of ascorbic acid, particularly at 150 mg L^{-1}, in improving growth and yield traits of soybean, with the best performance achieved by the Shaimaa cultivar.

KEYWORDS: Soybean cultivars, Ascorbic acid ،yield.

Received: 29/08/2025; **Accepted**: 05/11/2025; **Available online:** 31/12/2025

استجابة بعض أصناف فول الصويا (*Glycine max* L.) للرش بحامض الأسكوربيك في صفات ومكونات الحاصل

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الملخص

أُجريت هذه الدراسة في محطة أبحاث قسم المحاصيل الحقلية، كلية الزراعة، جامعة تكريت، خلال الموسم الصيفي لعام 2024، بهدف تقييم تأثير الرش الورقي بحامض الأسكوربيك في نمو وحاصل ثلاثة أصناف من فول الصويا ***(Glycine max L.)*** هي (شيماء، لي، لورا)، باستخدام أربعة تراكيز (0، 50، 100، 150 ملغم لتر$^{-1}$). نُفذت التجربة وفق تصميم القطاعات العشوائية الكاملة **(RCBD)** بترتيب الألواح المنشقة وبثلاث مكررات.
أظهرت النتائج أن الرش الورقي بحامض الأسكوربيك بتركيز 150 ملغم لتر$^{-1}$ أدى إلى تحسن معنوي في عدد من الصفات، شملت ارتفاع النبات (54.06 سم)، والمساحة الورقية (1982.99 سم^2 نبات$^{-1}$)، وعدد القرون (134.23 قرنة نبات$^{-1}$)، ووزن 500 بذرة (68.44 غم)، والحاصل الكلي (2.30 طن هكتار$^{-1}$). وعلى مستوى الأصناف، تفوق الصنف **شيماء** على بقية الأصناف في المساحة الورقية (2006.66 سم^2 نبات$^{-1}$)، وعدد القرون (133.62 قرنة نبات$^{-1}$)، ووزن 500 بذرة (67.46 غم)، مسجلًا أعلى حاصل كلي بلغ (2.30 طن هكتار$^{-1}$).
كما كان للتداخل بين الأصناف وتراكيز حامض الأسكوربيك تأثير معنوي، إذ حققت معاملة (شيماء × 150 ملغم لتر$^{-1}$) أعلى حاصل كلي بلغ (2.48 طن هكتار$^{-1}$)، في حين سجلت معاملة (لي × 0 ملغم لتر$^{-1}$) أدنى القيم في عدد من الصفات المدروسة. وتشير هذه النتائج إلى كفاءة الرش الورقي بحامض الأسكوربيك، ولا سيما بتركيز 150 ملغم لتر$^{-1}$، في تحسين صفات النمو والحاصل لمحصول فول الصويا، مع أفضل أداء للصنف شيماء.
الكلمات المفتاحية: أصناف فول الصويا، حامض الأسكوربيك، الحاصل.

INTRODUCTION

Soybean (Merrill) *Glycine max* L. is one of the most important oil crops in the world and is also of great importance as it belongs to the legume family Fabaceae and is of great importance among summer economic crops rich in amino acids, fatty acids, carbohydrates and mineral nutrients (Pagano, 2016; Jumaa & Hassan, 2025). Soybean cultivation has expanded remarkably in many countries since the mid-20th century. It was first introduced to Iraq in 1952 within research programs aimed at evaluating the suitability of climatic and environmental conditions for its production (Al-Humaidi, 1990). Varying cultivation areas were also allocated to soybean in several Arab countries, such as Iraq, Syria, and Egypt (AOAD, 1998). The genetic diversity of soybean comprises a wide range of genetic structures that can be utilized in the development of improved cultivars through selection and hybridization programs. Studying these genetic structures is a vital tool for understanding genetic variation and the relationships among cultivars, thereby facilitating the selection of superior genotypes and enhancing yield stability across different environments and growing seasons (Zhang et al., 2007). This type of research gains particular importance in regions characterized by harsh or fluctuating environmental conditions, such as semi-arid areas, where the choice of an appropriate genotype can make a significant difference in the physiological and productive performance of the crop. Several studies have shown that soybean genotypes differ in their responses to growth-promoting factors such as fertilizers, growth regulators, and environmental conditions, which necessitates precise and comprehensive evaluation (Specht et al., 1999). For instance, Al-Jumaili (2013) found significant differences among four soybean cultivars regarding leaf area, plant height, and branching. Al-Dawoodi and Al-Jubouri (2014) also revealed significant differences between cultivars (Sanaiya 2 and Lee74), with Sanaiya showing superiority in most traits at both experimental sites. Furthermore, Sarhan and Al-Jumaili (2015) indicated that cultivar Giza 22 was superior to Sanaiya 2 and Giza 35 in terms of leaf area, plant height, and branching. Within the framework of sustainable agriculture, bio-compounds such as ascorbic acid (Vitamin C) have attracted increasing attention. Ascorbic acid is considered one of the most important water-soluble antioxidants, , Abd El-Azeiz et al. (2021) reported that cultivar Giza 111 surpassed Giza 35, Giza 21, and Crawford cultivars in the number of pods per plant (129.26 pods), 100-seed weight, and seed yield per unit area (1894 kg feddan^{-1}). Likewise, Al-Abbasi (2023), in her study of four soybean cultivars (Lee, D, Shaimaa, and Laura), found that cultivar Shaimaa outperformed others in 100-seed weight (11.67 g), dry plant weight (328.43 g), individual plant yield (48.44 g plant^{-1}), and total yield (1.60 t ha^{-1}). Similarly, cultivar Laura recorded the highest mean number of pods per plant (125.58 pods plant^{-1}), with significant differences compared to other cultivars. In another study. playing a crucial role in protecting plant cells from environmental stresses by scavenging free radicals and stabilizing cell membranes (Smirnoff, 2018). It also contributes to enhancing enzymatic activities, regulating plant hormonal responses, and stimulating vegetative growth and flowering, which ultimately improves both yield quality and quantity (Khan et al., 2011; Akram et al., 2017). Al-Abaidi et al. (2016) investigated the foliar application of ascorbic acid on soybean using three concentrations (0.05, 0.1, and 0.15 g L^{-1}) and found that the highest concentration (0.15 g L^{-1}) resulted in the greatest number of branches (6.49–6.84 branches $plant^{-1}$), whereas the 0.1 g L^{-1} concentration gave the highest average plant height (84.88–89.19 cm). In a more recent study, Wavhale and Salve (2023) demonstrated that foliar application of plant growth regulators, particularly salicylic acid, significantly enhanced soybean leaf area. They found that increasing concentrations (50, 100, 150 mg L^{-1}) progressively raised leaf area to 1525.3, 1614.7, 1701.2 cm^2 $plant^{-1}$, respectively, compared to the control (1396.4 cm^2 $plant^{-1}$). Other research also confirmed that foliar spraying of ascorbic acid can enhance plant tolerance to salinity, drought, and heat stress through its effects on photosynthesis, ionic balance, and nutrient uptake efficiency. Additionally, it has been reported to increase pod number and seed weight, especially when used within well-planned programs that consider the appropriate timing and concentration of application. Accordingly, this study aims to evaluate the performance of soybean varieties under the influence of ascorbic acid on growth traits, yield and its components.

MATERIALS AND METHODS

A field experiment was conducted at the Research Station of the Field Crops Department – College of Agriculture, Tikrit University, during the summer season of 2024. The experiment was arranged in a randomized complete block design (RCBD) using a split-plot arrangement with three replications. The experimental unit area was 9 m^2 (3 x 3 m), giving a total of 36 experimental units, with each block containing 12 plots. Soybean seeds were sown on June 5, 2024, at a rate of 3–4 seeds per hill at a depth of 3 cm, then thinned to one plant per hill after the appearance of the third true leaf. Plant spacing was 20 cm between hills and 75 cm between rows. The soil was fertilized with urea (46% N) at a rate of 120 kg N ha^{-1}, half applied before sowing and the other half at the fourth-leaf stage. Triple superphosphate (46% P_2O_5) was also added at a rate of 80 kg P ha^{-1} in a single application before sowing. Ali (2021) Foliar spraying of ascorbic acid was performed using a 16-L backpack sprayer, applied twice: the first at the branching stage (V4) on July 10, 2024, and the second at the beginning of flowering (R1) on July 30, 2024, in the early morning to ensure absorption and minimize solution loss. Plants were irrigated by surface irrigation, and harvesting was carried out on October 10, 2024, at physiological maturity.

The experiment included two factors: Main plots (factor A – cultivars): three soybean cultivars: Shaimaa (C1), Lee (C2), and Laura (C3), obtained from the General Company for Industrial Crops, Iraqi Ministry of Agriculture.

Subplots (factor B – ascorbic acid concentrations): four concentrations: 0, 50, 100, and 150 mg L^{-1}. At the end of the season, the following traits were studied:

Plant height (cm): measured from the soil surface to the apical meristem of the main stem in five randomly selected plants from the middle rows of each plot using a measuring tape.

Leaf area (cm^2 $plant^{-1}$): calculated by the gravimetric method (Adel, 2012). Ten leaves per plant were randomly sampled, and leaf discs of known diameter were taken with a puncher, then oven-dried at 70°C for 24 hours and weighed using a sensitive balance. Leaf area was calculated using the standard formula, then multiplied by the total number of leaves per plant. Measurements were taken one week after spraying, again 30 days later, and finally at 70% flowering to obtain the total leaf area.

Number of leaves (leaves $plant^{-1}$): counted in five randomly selected plants per plot, and the mean was calculated.

Number of pods per plant (pods $plant^{-1}$): obtained by averaging the pod counts of five randomly selected plants.

Weight of 500 seeds (g): determined using a sensitive balance after manually counting and weighing 500 randomly collected seeds from the harvested plants.

Seed yield (t ha^{-1}): estimated from the yield of ten randomly sampled plants, multiplied by plant density per unit area, and then converted to hectare basis.

Statistical Analysis

Data were statistically analyzed using SAS software (SAS Institute, 2011) according to the factorial experiment in RCBD with a split-plot arrangement, where cultivars were assigned to the main plots and ascorbic acid concentrations to the subplots. Duncan’s Multiple Range Test (DMRT) was applied at a 0.05 probability level to compare means (Al-Rawi & Khalaf-Allah, 1980).

RESULTS AND DISCUSSION

1. Plant Height (cm)

Table (1) shows that foliar spraying with ascorbic acid, and their interactions had a significant effect on plant height. The highest concentration (150 mg L^{-1}) resulted in the tallest plants, with a mean height of 54.06 cm, followed by the 100 mg L^{-1} treatment. This indicates the positive role of ascorbic acid in promoting stem elongation through enhancing cell division and elongation as well as improving photosynthetic efficiency. These findings are consistent with those reported by Kuchlan and Kuchlan (2023), who found that foliar spraying with ascorbic acid at concentrations of 50, 100, and 200 mg L^{-1} at both vegetative (22–25 days after sowing) and pod-filling stages (57–60 days after sowing) increased plant height significantly. Regarding cultivars, Lee recorded the highest mean height (51.92 cm), although it was not significantly different from Shaimaa (51.92

cm) and Laura (50.00 cm).

The interaction effect between cultivar Lee and 150 mg L^{-1} ascorbic acid produced the tallest plants (59.50 cm) compared to other interactions. This highlights a positive interaction between the genetic background of the cultivar and the physiological response to ascorbic acid.

Table 1. Some of the soybean varieties respond to the Ascorbic acid in the characteristics of the result and its components to the plant height (cm)

Varieties	Ascorbic acid concentration (mg/ L^{-1})				Average varieties
	0	50	100	150	
Shaima	50.5 d	56 bc	43 ef	58.17 ab	51.92 a
Lae	41.17 f	54.33 c	57.17 a-c	59.5 a	53.04 a
Laura	58 ab	42.5 ef	55 bc	44.5 e	50 a
Average spray with ascorbic acid	49.89 c	50.94 bc	51.72 b	54.06 a	

Means followed by the same letter are not significantly different according to Duncan's Multiple Range Test at the 0.05 probability level.

2. Leaf Area (cm² plant⁻¹)

Table (2) indicates that foliar application of ascorbic acid had a significant effect on leaf area in soybean plants. The concentration of 150 mg L^{-1} recorded the highest mean value (1982.99 cm^2 $plant^{-1}$), which was not significantly different from 100 and 50 mg L^{-1}, but was significantly higher than the control (1787.74 cm^2 $plant^{-1}$). This progressive improvement can be attributed to the role of ascorbic acid in stimulating vegetative growth through enhancing cell division and elongation, activating metabolic processes associated with protoplasm and protein synthesis, and thereby promoting leaf expansion. Furthermore, ascorbic acid regulates water balance in leaf tissues and reduces stress factors affecting leaf development. These findings are consistent with those of Wu et al (2023), who reported that foliar application of growth regulators, including ascorbic acid, significantly improved vegetative growth traits of soybean, particularly leaf area, leading to enhanced photosynthetic capacity and overall plant growth. Similar results were also reported by Dolatabadian et al. (2010) and Ahmad et al. (2014).

Regarding cultivars, Shaimaa exhibited a significant superiority with the highest mean leaf area (2006.66 cm^2 $plant^{-1}$), which was statistically similar to Laura (1933.90 cm^2 $plant^{-1}$) but significantly higher than Lee (1778.19 cm^2 $plant^{-1}$). This variation is attributed to genetic differences in vegetative growth potential and physiological responses to external stimuli, as some cultivars are more efficient in utilizing ascorbic acid to enhance leaf expansion. These results are consistent with those of Al-Qaisi (2012).The interaction between cultivars and ascorbic acid concentrations was also significant. The combination of Shaimaa x 150 mg L^{-1} produced the highest mean leaf area (2634.86 cm^2 $plant^{-1}$), while the lowest value was observed in Shaimaa x 0 mg L^{-1} (1552.02 cm^2 $plant^{-1}$). This demonstrates a positive interaction between the genetic makeup of the cultivar and the optimum concentration of ascorbic acid.

Table 2. Effect of foliar application of ascorbic acid on leaf area (cm^2 $plant^{-1}$) in soybean cultivars

Varieties	Ascorbic acid concentration (mg/ L^{-1})				Average varieties
	0	50	100	150	
Shaima	1552.02 e	1860.34 cd	1979.4 bc	2634.86 a	2006.66 a
Lae	1910.33 b-d	1917.84 b-d	1710.27	1574.33 e	1778.19 b
Laura	1900.87 b-d	1937.60 b-d	2157.34 b	1739.79 c-e	1933.9 a
Average spray with ascorbic acid	1787.74 b	1905.26 ab	1949 a	1982.99 a	

3. Number of Leaves (No. $plant^{-1}$)

Table (3) shows that the individual effects of both soybean cultivars and ascorbic acid concentrations were not significant for the number of leaves per plant. However, the interaction between cultivars and concentrations exhibited significant differences, indicating that the response depended on the genetic background of the cultivar combined with the physiological treatment. The interaction Shaimaa x 150 mg L^{-1} produced the highest mean number of leaves (42 leaves $plant^{-1}$), followed by Laura x 100 mg L^{-1} (41 leaves $plant^{-1}$). In contrast, the lowest mean was recorded by Lee x 100 mg L^{-1} (31 leaves $plant^{-1}$).

These findings emphasize that the effectiveness of ascorbic acid foliar application is largely cultivar-dependent, as not all genotypes respond equally to growth stimulants. This suggests the necessity of selecting suitable genetic structures that exhibit optimal physiological responses to treatments aimed at enhancing vegetative traits such as leaf number.

Table 3. Response of soybean cultivars to foliar application of ascorbic acid in number of leaves (leaves $plant^{-1}$).

Varieties	Ascorbic acid concentration (mg/ L^{-1})				Average varieties
	0	50	100	150	
Shaima	35 cd	31.67 d	38.33 b-c	42 a	36.75 a
Lae	36.33 a-d	38.67 b-c	31.00 d	32.00 d	34.5 a
Laura	32 d	36 b-c	41 ab	36.33 a-d	36.33 a
Average	34.44 a	35.45 a	36.78 a	36.78 a	

spray with ascorbic acid

4. Number of Pods (No. plant^{-1})

Table (4) demonstrates that foliar application of ascorbic acid significantly influenced the number of pods per plant. The highest concentration (150 mg L^{-1}) produced the largest mean pod number (134.23 pods plant^{-1}), while the control treatment (0 mg L^{-1}) recorded the lowest mean (125.56 pods plant^{-1}). This increase may be attributed to the role of ascorbic acid in enhancing the number of fruiting branches (see Table 9), which positively affected pod formation. Additionally, ascorbic acid contributes to stimulating flowering and pod set by regulating the hormonal balance between auxins and cytokinins, thereby increasing the conversion rate of flowers into pods. These results are consistent with Kuchlan and Kuchlan (2023), who found that foliar spraying with ascorbic acid at concentrations of 50, 100, and 200 ppm during vegetative and pod-filling stages led to significant improvements in growth and yield traits of soybean, including pod number. Regarding cultivars, Shaimaa recorded the highest mean pod number (133.62 pods plant^{-1}), which was not significantly different from Laura (132.68 pods plant^{-1}), while Lee had the lowest value (128.59 pods plant^{-1}). This variation is attributed to genetic differences in pod-setting efficiency, physiological response to ascorbic acid, and the distribution of photosynthates to reproductive organs. Similar results were reported by Keisham et al. (2021) and Al-Abbasi (2023).

As for the interaction, it was also significant. The combination Laura x 50 mg L^{-1} recorded the highest pod number (142.7 pods plant^{-1}), which did not differ significantly from Shaimaa x 150 mg L^{-1} and Lee x 150 mg L^{-1}. The lowest value was observed in Laura x 0 mg L^{-1} (122.0 pods plant^{-1}).

These findings indicate that ascorbic acid enhances pod formation in soybean, but the magnitude of response varies depending on both genetic and physiological factors, making the choice of cultivar and concentration critical for optimizing yield.

Table 4. Response of soybean cultivars to foliar application of ascorbic acid in number of pods (pods plant^{-1}).

Varieties	Ascorbic acid concentration (mg/ L^{-1})				Average varieties
	0	50	100	150	
Shaima	129.00 c-e	136.00 a-c	131.33 b-c	138.13 ab	133.62 a
Lae	125.67 de	122.00 e	133.13 b-c	133.57 b-c	128.59 b
Laura	122.00 e	142.7 a	135.00 a-c	131.00 b-c	132.68 a
Average	125.56 b	133.57 a	133.15 a	134.23 a	

spray with ascorbic acid					

5. Weight of 500 Seeds (g)

Table (5) shows that the weight of 500 seeds in soybean was significantly affected by foliar application of ascorbic acid. The highest concentration (150 mg L^{-1}) gave the heaviest seed weight (68.44 g), which differed significantly ($p \leq 0.05$) from the other concentrations (0, 50, and 100 mg L^{-1}), recording 61.33 g, 62.50 g, and 64.39 g, respectively. This increase in seed weight under higher concentrations reflects the positive role of ascorbic acid in improving dry matter accumulation within seeds and enhancing photosynthetic efficiency as well as assimilate translocation to the grains. These findings are consistent with Al-Abaidi et al. (2016).

Concerning cultivars, Shaimaa recorded the highest mean seed weight (67.46 g), significantly surpassing Lee (62.33 g) and Laura (62.71 g), which did not differ significantly from each other. This superiority is attributed to genetic variations among cultivars in seed-filling ability and nutrient accumulation. Similar conclusions were reported by Al-Rawi (2020) and Timotiwu (2020), who found notable differences in seed weight among soybean cultivars.

The interaction effect was also significant. The combination Laura x 50 mg L^{-1} achieved the highest mean (69.50 g), followed closely by Lee x 150 mg L^{-1} (69.33 g).

Overall, these findings suggest that foliar application of ascorbic acid positively influences seed weight in soybean, with higher concentrations generally leading to better results. However, the magnitude of response varied depending on cultivar and concentration, highlighting the importance of genotype x treatment interactions.

Table 5. Response of soybean cultivars to foliar application of ascorbic acid in weight of 500 seeds (g).

Varieties	Ascorbic acid concentration (mg/ L^{-1})				Average varieties
	0	50	100	150	
Shaima	68.00 ab	65.33 a-c	68.50 ab	68.00 ab	67.46 a
Lae	61.00 b-d	52.67 e	66.33 ab	69.33 a	62.33 b
Laura	55.00 de	69.50 a	58.33 c-e	68.00 ab	62.71 b
Average spray with ascorbic acid	61.33 b	62.50 b	64.39 b	68.44 a	

6. Total Seed Yield (Ton ha^{-1})

Table (6) shows that the total seed yield of soybean was significantly affected by foliar application of ascorbic acid. The concentration of 150 mg L^{-1} recorded the highest mean yield (2.30 t ha^{-1}), which did not differ significantly from 100 mg L^{-1} (2.27 t ha^{-1}), but both were significantly superior to 50 mg L^{-1} (2.00 t ha^{-1}) and the control treatment (1.97 t ha^{-1}). The gradual increase in yield reflects the positive effect of ascorbic acid on improving yield components (Tables 10, 11, and 12), thereby enhancing the plant's physiological efficiency in assimilate production and distribution toward seeds. These findings are consistent with Miladinov et al. (2020), who also reported significant yield improvements in soybean under foliar application of ascorbic acid.

Regarding cultivars, Shaimaa recorded the highest mean yield (2.30 t ha^{-1}), which did not differ significantly from Lee (2.17 t ha^{-1}), while Laura produced the lowest yield (1.93 t ha^{-1}). This indicates that Shaimaa and Lee possess superior genetic and physiological capacities to utilize resources efficiently and achieve higher productivity. Similar results were reported by Mohammed et al. (2019) and Karges et al. (2022).

The interaction effect was also significant. The combination Lee x 100 mg L^{-1} achieved the highest total yield (2.64 t ha^{-1}), followed by Shaimaa x 150 mg L^{-1} (2.48 t ha^{-1}). The lowest yield was recorded in Laura x 50 mg L^{-1} (1.64 t ha^{-1}). These results confirm that yield performance depends on both cultivar genetic potential and the physiological effect of ascorbic acid, with the best results achieved under optimal genotype x concentration combinations.

Table 6. Response of soybean cultivars to foliar application of ascorbic acid in total seed yield (t ha^{-1}).

Varieties	Ascorbic acid concentration (mg/ L^{-1})				Average varieties
	0	**50**	**100**	**150**	
Shaima	2.20 ab	2.21 ab	2.30 ab	2.48 a	2.30 a
Lae	1.68 b	2.14 ab	2.64 a	2.23 ab	2.17 ab
Laura	2.04 ab	1.64 b	1.86 ab	2.18 ab	1.93 b
Average spray with ascorbic acid	1.97 b	2.00 b	2.27 a	2.30 a	

CONCLUSION

In conclusion, the evaluation of 20 hybrids revealed considerable variability in their performance, with high heritability (h^2_B) for the majority of traits. Multivariate statistical analysis

(CA and PCA) of phenotypic data clustered the 20 sweet and forage corn hybrids into six distinct heterotic groups. Positive correlations, as determined by biplot analysis, were observed between E.Y. and several traits, including E.W., E.L., N.K.R.E., N.L.P., E.H., P.H., N.E.L., L.A., S.D., and N.E.P. This knowledge will aid in identifying genotypes that can enhance the genetic foundation in programs aimed at improving sweet and forage corn. A correlation plot (PCs 1–3) explained 76.26% of the variation across the datasets, indicating significant variation among the traits.

Additional research should focus on collecting, characterizing, and utilizing imported sweet and forage corn single-cross hybrids to select the most adaptive hybrid to be grown in the Kurdistan Region of Iraq. Since phenotypic data could be affected by environmental factors, to verify these findings, analysis of molecular variations could be performed on the single-cross hybrids as an additional tool to assist in the selection process for superior hybrids. At the end, CA and PCA are appropriate tools to distinguish genotypes; therefore, I suggest using them continuously for further research.

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