

Evaluation of the field performance of cowpea genotypes and their diallel cross under the influence of boron foliar spraying

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Abstract

The study was conducted during the 2024/2025 seasons in Baquba nursery of the Diyala Agriculture Directorate to study 12 cultivars of cowpea and evaluate the performance of their individual hybrids under the influence of spraying with two levels of boron (0-100) ml. L⁻¹. The first season included the cultivation of cowpea cultivars. When the seeds germinated and the seedlings reached the appropriate size, samples were taken from the leaves to determine the genetic distance between the cultivars and to find their genetic fingerprint using the ISSR technique. On the basis of the results obtained, 6 cultivars with the greatest genetic divergence between them were chosen, which are (Romshron - NaNa - Riyadh - Black eye - Leader - White Local).

These six cultivars were grown in the first agricultural season, and when they reached the flowering stage, they were introduced into diallel cross program to produce first-generation F1 hybrids. In the second agricultural season, a comprehensive comparison of the genetic compositions was conducted, which included 15 hybrids and 6 parents. To study the effect of boron, plants were sprayed with boron. The experiment was carried out according to a split plot design within a randomized complete block design (RCBD) with three replicates. The data were analyzed statistically using the statistical analysis program SAS, and the averages were compared using the Multiple Range Test Duncan, s, at a probability level of 0.05 .

The results of spraying with boron showed of several parents excelled in traits of vegetative growth. The father (5) (Leader) was excelled in traits of per-plant yield, total yield, and pod weight. The father (3) (Al-Riyadh) was excelled in traits of pod length and number of seeds, and the father (4) (Black Eye) was excelled in the number of pods .The results of the analysis showed that the 1x3 hybrid was significantly excelled in traits of average pod weight, number of seeds, and pod length, while the 1x5 hybrid was significantly excelled in traits of per-plant yield and total yield, and the 4x2 hybrid was excelled in number of pods. The results of the study showed that spraying with boron produced significant effects in all the studied traits, where the spraying treatment with boron excelled the concentration of 100 ml. L⁻¹ achieved the highest values for all the studied traits.

Introduction

Cowpeas are an important legume crop worldwide, cultivated in tropical and subtropical regions due to their high adaptability to harsh environmental conditions, particularly high temperatures and limited water resources. They are also a staple food

crop in many developing countries because of their significant nutritional and economic value. [12] Cowpeas are characterized by their high nutritional content. Their seeds contain good levels of protein, vitamins, and minerals, making them an important and low-cost source of plant protein, especially in areas lacking

animal protein[3,12] [In addition to their nutritional importance, cowpeas play a significant role in improving soil fertility through their ability to fix atmospheric nitrogen in symbiosis with root nodule bacteria. This contributes to reducing the need for nitrogen fertilizers and improving the productivity of subsequent crops within different crop rotations. [1] Cowpeas contain a number of bioactive compounds, such as phenolic compounds, peptides, and dietary fiber, which contribute to enhanced antioxidant activity and may help reduce the risk of developing certain chronic diseases. This has increased researchers' interest in studying their health and nutritional benefits [5].

Various plant parts, such as the green pods, leaves, and dry seeds, are utilized for various food and fodder purposes, making cowpeas a versatile crop of increasing importance in achieving food security and sustainable agricultural development [9]. Due to their nutritional, economic, and agricultural importance, cowpeas have received extensive attention in scientific research aimed at improving their productivity, quality traits, and increasing their tolerance to different environmental conditions, thus contributing to enhancing food security and achieving sustainable agricultural development (FAO, 2023). Foliar nutrition is an effective agricultural technique for supplying plants with nutrients during periods of increased nutrient demand, as well as for addressing nutritional deficiencies. Nutrients are absorbed through the leaf surface via stomata and epidermis, then transported to plant tissues and cells for use in various biological processes [15]. Numerous studies have indicated that foliar spraying is more effective at correcting nutrient deficiencies compared to soil fertilization, positively impacting vegetative growth and productivity, and contributing to increased fertilizer use efficiency and reduced application rates [13]. Foliar nutrition complements soil fertilization by delivering nutrients uniformly to vegetative growth, thus

enhancing plant uptake. This technique also reduces the energy required for nutrient transport within the plant and ensures adequate nutrient supply during critical growth periods. Despite the numerous advantages of this method, its success requires repeated spraying throughout the growing season to ensure the plant's nutritional requirements are consistently met [7,8]. Boron is an essential micronutrient that significantly contributes to increased plant productivity through its influence on numerous vital processes. Its role begins with pollination and fertilization, where it stimulates pollen grains and accelerates cell division in the floral parts. It also promotes pollen tube growth within the stigma, leading to increased fruit set and, consequently, higher yields. Furthermore, it activates several important enzymes, such as catalase and peroxidase, which are involved in regulating many vital plant functions. Boron also strengthens the cell wall through its role in the formation of lignin and pectin compounds, as it is present in high concentrations within the cell wall[11]. Additionally, it participates in the transport of sugars from their synthesis sites to their storage sites due to its tendency to bind to hydroxyl groups in organic compounds such as polysaccharides. In addition, it increases the rate of synthesis of ribonucleic acid (RNA), plant hormones, and proteins, and it enhances the binding of phosphorus to nucleotides, which leads to an improvement in the process of synthesis of nucleic acids associated with protein production within the plant [4]. [10] investigated the effect of boron spraying on cowpea plants. Boron significantly improved the urban growth of cowpea. Foliar spraying with boron at concentrations of 100 and 200 mg.L⁻¹ resulted in a significant increase in cowpea plant height and leaf area compared to no spraying. Furthermore, the 200 mg/L concentration led to a significant increase in both fresh and dry plant weight. [16] conducted a recent study evaluating the effect of different boron concentrations (0, 1500, 3000, and 6000 g B/ha) on cowpea growth and yield. The results showed highly significant differences (P<0.01) in most traits,

such as flowering period, which ranged from 56 to 75 days. The pod length ranged from 14.92 to 17.88 cm, and its width from 5.28 to 7.54 mm. Seed yield per plant ranged from 26.74 to 38.99 g/plant, and the number of nodules per plant ranged from 9.26 to 42.53.

2- Materials and Methods

Cowpea seedlings were sown on during the 2024/2025 seasons, in Baquba nursery belonging to the Diyala Agriculture Directorate. A factorial experiment with two factors was conducted using a split-plot design with a randomized complete block design (RCBD) and three replicates. The first factor was the genotype, comprising 6 parents and 15 Diallel cross. The second factor was boron spraying at two levels (0 and 100 ml. L⁻¹, spray levels were set in the main plots and genotypes were set in the sub-plots. Seeds were sown in rows along the side of drip irrigation pipes, with a distance of 0.75m between rows, 1m between replicates, and 0.2m between plants. Each replicate contained 7 rows, and the parents and hybrids were randomly distributed. Thus, each replicate contained 42 genotypes, both sprayed and unsprayed, resulting in a total of 126 experimental units. Plant care operations, including weeding, irrigation, hoeing, and pest control, were conducted as needed. Based on the results of the genetic fingerprint, 6 cultivars were selected from among 12 cultivars, namely (Romshron-NaNa - Riyadh-Black eye- Leader - Local White) based on the genetic divergence between them that appeared in the genetic fingerprint test. Weeding and pest control operations were carried out as needed, and at the flowering stage, they were included in the half diallel cross program according to the first method and the fixed model of the Griffing (1956) methods to produce first generation F1 hybrids, and the study measurements were carried out on them.

Yield Traits and Components:

Average pod weight (g pod⁻¹)

The weight of pods from five plants per experimental unit was measured, and the average was calculated.

Number of pods (pod plant⁻¹)

The number of pods from five plants in the experimental unit was counted cumulatively at the end of the season, and the average was calculated.

Number of seeds per pod (seed pod⁻¹)

Seeds from five plants were extracted randomly from each experimental unit for three harvests at the beginning and middle of the season.

Pod length (cm pod⁻¹)

The pod length of five plants in each experimental unit for three harvests at the beginning and middle of the season was measured using a metal strip, and the average was calculated.

Yield per plant (kg plant⁻¹)

The yield was harvested every 7 days. After collecting the harvests from each experimental unit, the yield was calculated by dividing the cumulative yield of the experimental unit by the number of plants in the experimental unit. Total yield (tons.ha⁻¹)

Total yield (tons.ha⁻¹) = Experimental unit yield * Area (hectares) / Area (experimental unit)

3- Results and Discussion

3-1 Yield Traits and Components:

3-1-1 Pod weight (g)

The results in Table (1) show that boron spraying has a significant effect on the studied characteristic. Spraying with boron at a concentration of 100 ml.L⁻¹ resulted in an increase in pod weight of (5.246) g compared to the control treatment, where the pod weight reached (4.806) g. The results in the same table indicate significant differences between the

genotypes. Father (5) showed the highest pod weight at 5.270 g, while Father (4) recorded the lowest at 3.621 g. Hybrid (1*3) produced the highest pod weight at 6.684 g, while hybrid (2*4) had the lowest at 3.579 g. The interaction between the genotypes and the boron spray level had a significant effect on the studied trait, with Father (6) exhibiting the highest value at a 100 ml spray concentration.

The pod weight reached (6.047) g.L⁻¹, while the parent (4) gave the lowest value at the no-spray level, which was (3.520) g. As for the hybrids, the hybrid (1*3) was distinguished by the highest pod weight, which was (7.345) g at the concentration level of 100 ml.L⁻¹, while the hybrid plants (2*4) gave the lowest pod weight, which was (3.466) g, in the control treatment.

Table (1) shows the effect of genotype (parents and their individual hybrids) and boron spraying on the average pod weight (g.pod⁻¹) of cowpea plants

genotypes	Boron levels		Average effect of genotypes
	0	100ml.L ⁻¹	
1	4.887 ml	5.233 hkgjfi	5.060 GF
2	4.718 nm	5.131 hkji	4.924 G
3	5.430 edf	6.047 b	5.738 B
4	3.520 st	3.721 r	3.621 K
5	5.156 hkji	5.383 egdf	5.270 E
6	4.876 ml	5.099 kji	4.987 GF
1*2	5.165 hkgji	5.450 edf	5.308 E
1*3	6.023 b	7.345 a	6.684 A
1*4	3.731 r	3.812 r	3.772 J
1*5	5.329 hegdf	5.848 cb	5.588 C
1*6	5.289 hegdfi	5.507 d	5.398 DE
2*3	5.254 hgjfi	5.422 edf	5.338 E
2*4	3.466 t	3.691 sr	3.579 K
2*5	5.028 kl	5.165 hkgji	5.097 F
2*6	4.573 nop	5.385 egdf	4.979 GF
3*4	4.490 op	4.442 p	4.466 I
3*5	5.486 ed	6.029 b	5.757 B
3*6	5.307 hegdfi	5.749 c	5.528 DC

4*5	4.135 q	5.378 egdf	4.756 H
4*6	4.409 p	5.050 kjl	4.729 H
5*6	4.654 no	5.275 hegfi	4.965 GF
Average boron effect	4.806 B	5.246 A	

The mean values of data with the same letter do not differ from each other according to Duncan's multiple range test at a 5% probability level.

3.1.2 Number of pods per cowpea plant (pod. plant⁻¹)

The results in Table (2) show that spraying with boron had a significant effect on the studied trait. Using it at a concentration of 100 ml.L⁻¹ resulted in the production of (240.3) pods .plant⁻¹, compared to the control treatment which recorded (188.4) pods .plant⁻¹. The results in the same table confirmed the existence of significant differences between the genotypes with respect to this trait, reflecting clear genetic variation between the parents. Parent (4) recorded the highest number of pods, reaching (246.5) pods .plant⁻¹. The parent (3) achieved the lowest number of pods at 172.3 pods per plant. This variation was reflected in the resulting hybrid plants,

Table (2) shows the effect of genotypes (parents and their individual hybrids) and boron spraying on the number of pods (pods .plant⁻¹) of cowpea plants.

with hybrid (2*4) producing the highest number of pods at 281.0 pods .plant⁻¹, while hybrids (6*1) and (3*6) had the lowest, recording 200.1 and 199.6 pods .plant⁻¹, respectively. The interaction between genotypes and boron application level had a significant effect on the studied trait. Parent (4) achieved the highest value at a concentration of 100 ml.L⁻¹, at 272.6 pods .plant⁻¹. Plant, while parent (3) recorded the lowest value in the control treatment at (167.6) pods .plant⁻¹. At the hybrid level, hybrid (1*4) showed a significant advantage in the number of pods at a concentration of 100 ml.L⁻¹, recording (316.6) pods .plant⁻¹, while hybrid (2*3) recorded the lowest number at (160.0) pods/plant in the no-spray treatment.

genotypes	Boron levels		Average effect of genotypes
	0	100ml.L ⁻¹	
1	191.6 kl	211.6 ih	201.6 IH
2	177.6 mno	200.0 kj	188.3 J
3	167.6 pqo	177.0 mno	172.3 K
4	220.3 gh	272.6 b	246.5 C
5	192.3 kl	223.3 gf	207.5 GH
6	179.3 mn	198.6 kj	189.0 J
1*2	183.3 ml	225.3 gf	204.3 IH
1*3	171.0 pno	201.0 kj	186.0 J

1*4	225.6 gf	316.6 a	271.1 B
1*5	195.3 kj	264.6 cb	230.0 D
1*6	172.3 pno	228.0 gf	200.1 I
2*3	160.0 q	243.3 ed	201.6 IH
2*4	238.0 ed	324.0 a	281.0 A
2*5	180.6 mn	269.0 cb	224.8 ED
2*6	179.6 mn	244.6 d	212.1 GF
3*4	194.3 kj	243.0 ed	218.6 EF
3*5	177.0 mno	240.0 ed	208.5 GH
3*6	165.6 pq	233.6 ef	199.6 I
4*5	203.3 ij	247.6 d	225.5 ED
4*6	184.0 ml	221.6 g	202.8 IH
5*6	197.6 kj	262.0 c	229.8 D
Average boron effect	188.4 B	240.3 A	

The mean values of data with the same letter do not differ from each other according to Duncan's multiple range test at a 5% probability level.

3.1.3 Number of seeds per pod (seed pod⁻¹)

Table 3 shows that boron spraying significantly affected the studied trait. Using boron at a concentration of 100 ml.L⁻¹ resulted in the production of 9.127 seed pod⁻¹, compared to the control treatment which recorded 8.035 seed pod⁻¹. The same table indicates significant differences between the genotypes regarding this trait, demonstrating clear genetic variation between the parents. Parent (3) recorded the highest number of seeds per pod, at 10.22 seed pod⁻¹, while parent (4) recorded the lowest number of seeds, at 7.610 seed pod⁻¹. This variation was reflected in the resulting hybrid plants. Hybrid

(1*3) showed excelled, producing 11.00 seeds per pod, while hybrid (2*4) was the least productive, recording 6.795 seed pod⁻¹. The interaction between genotypes and boron spray level showed a significant effect on the studied trait. Parent (3) achieved the highest seed count per pod at a concentration of 100 ml.L⁻¹, recording 11.11 seeds per pod, while parent (4) had the lowest value in the control treatment, with 6.55 seed pod⁻¹. At the hybrid level, hybrid (1*3) was excelled in seed production, recording 11.66 seed pod⁻¹ at a concentration of 100 ml.L⁻¹, while hybrid (2*4) was the least productive, achieving 6.59 seed pod⁻¹ in the control treatment.

Table (3) shows the effect of genotypes (parents and their individual hybrids) and boron spraying on the number of seeds (seed pod⁻¹) of cowpea plants.

genotypes	Boron levels		Average effect of genotypes
	0	100ml.L ⁻¹	
1	7.78 klm	9.83 cebd	8.806 GFE
2	7.27 mn	9.22 gefh	8.250 HJI
3	9.33 gefd	11.11 a	10.22 B
4	6.55 o	8.66 gih	7.610 KML
5	8.77 gifh	10.11 cb	9.443 DC
6	7.88 kmjl	8.77 gifh	8.331 GHJI
1*2	7.89 kmjl	9.00 gifh	8.445 GHFI
1*3	10.33 b	11.66 a	11.00 A
1*4	7.00 on	7.83 kmjl	7.416 ML
1*5	8.55 ijh	9.16 gefh	8.861 FE
1*6	7.66 mnl	8.33 kijl	8.000 KJI
2*3	8.33 kijl	9.89 cebd	9.111 DCE
2*4	6.59 o	7.00 on	6.795 N
2*5	8.33 kijl	9.44 cefd	8.888 FE
2*6	7.33 mn	8.44 kjih	7.890 KJL
3*4	7.22 omn	7.50 mn	7.361 M
3*5	9.16 gefh	10.00 cbd	9.583 C
3*6	8.33 kijl	8.89 gifh	8.611 GHFE
4*5	8.89 gifh	8.89 gifh	8.888 FE
4*6	6.99 on	8.44 kjih	7.721 KML
5*6	8.50 kjih	9.44 cefd	8.973 DE
Average boron effect	8.035 B	9.127 A	

The means of data with similar letters do not differ from each other according to Duncan's multiple range test at a 5% probability level.

3.1.4 Pod Length (cm)

The results in Table (4) show that boron spraying has a significant effect on the trait. A concentration of 100 ml L⁻¹ resulted in an increase in pod length of 17.49 cm compared to the control treatment of 15.28 cm. The same table also shows significant differences between the genotypes for this trait. Parent (3) showed an increase in pod length of (20.13) cm, while parent (4) produced the smallest pod length of (13.60) cm. The variation in pod length between the parents had a clear effect

on the hybrids. The hybrid (3*1) produced an increase in pod length of (21.75) cm, while the hybrid (2*4) produced the smallest pod length of (13.25) cm. The interaction had a significant effect on the trait. Parent (3) gave the highest pod length value of 21.37 cm at a spray level of 100 ml L⁻¹, while parent (4) recorded the lowest value of 11.77 cm when no spraying was applied. For the hybrids, hybrid (3*1) showed an increase in pod length to 23.83 cm when sprayed at a concentration of 100 ml L⁻¹, while hybrid (4*2) showed a decrease to 12.66 cm in the control treatment.

Table (4) shows the effect of genotypes (parents and their individual hybrids) and boron spraying on pod length (cm) of cowpea plants.

genotypes	Boron levels		Average effect of genotypes
	0	100ml.L-1	
1	16.83 ij	18.44 de	17.68 D
2	14.00 rs	16.88 ij	15.43 H
3	18.94 b	21.37 b	20.13 B
4	11.77 t	15.44 onlm	13.60 LK
5	15.94 klm	17.94 feg	16.94 EF
6	14.83 poq	16.00 kl	15.41 H
1*2	15.72 knlm	17.38 ihg	16.55 F
1*3	19.66 c	23.83 a	21.75 A
1*4	13.33 s	14.77 poq	14.05 JK
1*5	15.50 onlm	18.88 d	17.19 ED
1*6	15.05 ponq	17.11 ih	16.08 G
2*3	17.66 fhg	19.16 dc	18.41 C
2*4	12.66 t	14.33 rq	13.25 L
2*5	16.05 kj	17.99 feg	17.02 ED
2*6	14.88 poq	16.38 kj	15.63 HG
3*4	13.61 s	14.94 poq	14.27 JI

3*5	15.22 ponm	19.11 dc	17.16 ED
3*6	15.38 onlm	18.16 fe	16.77 EF
4*5	14.66 prq	15.88 klm	15.27 H
4*6	14.00 rs	15.44 onlm	14.72 I
5*6	15.83 klm	18.00 feg	16.91 EF
Average boron effect	15.28 B	17.49 A	

The averages of data with the same letter do not differ from each other according to Duncan's multiple range test at a 5% probability level.

3.1.5 Yield per plant (kg plant^{-1})

The results in Table (5) show that boron spraying had a significant effect on the studied trait. Yield increased to ($1.240 \text{ kg plant}^{-1}$) at a concentration of 100 mL.L^{-1} , compared to ($0.892 \text{ kg plant}^{-1}$) in the control treatment. The results in the table revealed a clear genetic variation between the genotypes. Significant differences appeared between the parents in this trait. Parent (5) achieved the highest yield of (1.097 kg plant), while parent (4) recorded the lowest yield of ($0.893 \text{ kg plant}^{-1}$). This variation was reflected in the hybrids, with hybrid (1*5) outperforming them with a yield

of ($1.294 \text{ kg plant}^{-1}$). Plant, while the hybrid (4*6) was the least productive at ($0.965 \text{ kg plant}^{-1}$). The interaction between genotypes and boron spray level showed a significant effect on the studied trait. The parent (5) achieved the highest productivity at a concentration of 100 mL.L^{-1} , recording (1.202 kg/plant), while the lowest productivity for the parent (4) at the no-spray level was ($0.775 \text{ kg plant}^{-1}$). At the hybrid level, the hybrid (1*5) excelled others with the highest productivity, reaching ($1.547 \text{ kg plant}^{-1}$) at a concentration of 100 mL.L^{-1} , while the hybrid (4*6) was the least productive, achieving ($0.811 \text{ kg plant}^{-1}$) in the control treatment.

Table (5) shows the effect of genotypes (parents and their individual hybrids) and boron spraying on the yield per plant (kg.plant^{-1}) of cowpea plants

genotypes	Boron levels		Average effect of genotypes
	0	100 mL.L^{-1}	
1	0.936 q	1.107 j	1.022 I
2	0.838 t	1.025 ml	0.932 M
3	0.909 r	1.070 k	0.989 K
4	0.775 v	1.011 mn	0.893 N
5	0.991 on	1.202 i	1.097 FE
6	0.875 s	1.013 mn	0.944 M
1*2	0.959 p	1.227 h	1.093 FG
1*3	1.030 ml	1.476 b	1.253 B

1*4	0.842 t	1.206 h	1.024 I
1*5	1.041 l	1.547 a	1.294 A
1*6	0.911 r	1.255 g	1.083 FGH
2*3	0.840 t	1.319 f	1.080 GH
2*4	0.825 ut	1.187 i	1.006 J
2*5	0.908 r	1.389 d	1.148 D
2*6	0.821 ut	1.317 f	1.069 H
3*4	0.872 s	1.079 k	0.976 LK
3*5	0.971 op	1.446 c	1.208 C
3*6	0.879 s	1.342 e	1.111 E
4*5	0.840 t	1.315 f	1.077 GH
4*6	0.811 u	1.119 j	0.965 L
5*6	0.920 rq	1.381 d	1.150 D
Average boron effect	0.892 B	1.240 A	

The means of data with similar letters do not differ from each other according to Duncan's multinomial test under the 5% probability level.

3-1-6 Total yield (tons ha⁻¹)

The results of Table (6) showed that spraying with boron led to a significant effect on the studied trait, as production reached (24.81) tons ha⁻¹ at concentration of 100 ml. L⁻¹, compared to (17.90) tons ha⁻¹ when control treatment. The results of the same table revealed that there were significant differences between the genotypes for this trait. Father (5) recorded the highest yield of (21.93) tons ha⁻¹, while the father (4) recorded the lowest yield of (17.98) tons ha⁻¹. This discrepancy was reflected in the resulting hybrid plants, as the hybrid (1*5) excelled, achieving (25.90) tons ha⁻¹, while the hybrid (3*4) and hybrid (4*6)

recorded the lowest yields of (19.50) and (19.39) tons ha⁻¹,

The interaction between genotypes and the level of boron spraying showed a significant effect on the studied trait. Father (5) recorded the highest result at a concentration of 100 ml. L⁻¹, and reached (24.04) tons ha⁻¹, while the lowest productivity of parent (4) in control treatment was (15.50) tons. As for hybrids, the hybrid (1*5) had the highest productivity, reaching (30.95) tons ha⁻¹ at concentration of 100 ml. L⁻¹, while the hybrid (4*6) was the least productive, achieving (16.22) tons ha⁻¹ at the non-spraying level.

Table (6) shows the effect of genotypes (of parents and their individual hybrids) and spraying with boron on the total plant yield (tons ha⁻¹) of cowpea plants.

genotypes	Boron levels		Average effect of genotypes
	0	100ml.L-1	
1	18.74 p	22.15 j	20.44 I
2	16.77 s	20.51 ml	18.64 M
3	18.25q	21.40 k	19.82 K
4	15.50 u	20.29 m	17.89 N
5	19.83 n	24.04 i	21.93 F
6	17.49 r	20.25 m	18.87 M
1*2	19.17 o	24.55 h	21.86 F
1*3	20.56 ml	29.52 b	25.04 B
1*4	16.84 s	24.13 ih	20.48 I
1*5	20.85 l	30.95 a	25.90 A
1*6	18.23 q	25.12 g	21.67 FGH
2*3	16.81 s	26.37 f	21.59 GH
2*4	16.50 ts	23.74 i	20.12 J
2*5	18.16 q	27.78 d	22.97 D
2*6	16.43 ts	26.33 f	21.38 H
3*4	17.41 r	21.58 k	19.50 L
3*5	19.41 o	28.93 c	24.17 C
3*6	17.58 r	26.85 e	22.21 E
4*5	16.81 s	26.30 f	21.55 GH
4*6	16.22 t	22.56 j	19.39 L
5*6	18.39 qp	27.63 d	23.01 D
Average boron effect	17.90 B	24.81 A	

Data with similar letter values do not differ from each other according to Duncan's multiple range test at a 5% probability level.

4- Discussion of Yield Traits and Components:

The results in Tables (1-2-3-4-5-6) show a significant difference between the genotypes. This is due to the variation in genes carried by the parents and hybrids, which in turn leads to differences in the studied traits. This variation reflects the diversity of genotypes and the differences in the resulting hybrids. This is a positive indicator that can be used as a foundational approach to further genetic analysis of these traits and to estimate the components of genetic variation and the gene action affecting them. These differences are essential for completing the genetic analysis and represent clear evidence of genetic variation, thus providing an opportunity to select the most superior genotypes. One genotype excelled on another is attributed to the existence of complex interactions between the unique genotype of each genotype and the environmental conditions in which that genotype lives. The interaction of genes with the environment does not mean that genes alone determine plant traits. Rather, it interacts with the prevailing environmental conditions in the region where the plant grows, and the same gene can produce different results in different environments. For example, a specific gene produces large fruits in a nutrient-rich environment, while the same gene produces small fruits in a nutrient-poor environment. The reason for the variation in genotypes in yield traits is that each genotype (purebred or hybrid) carries a different genotype. This genotype determines the set of hereditary traits that the hybrid inherits from its parents, such as the yield traits and their components.

Studies have shown that improvements in the vegetative traits of cowpea plants, such as increased leaf area, higher chlorophyll content, increased number of leaves, and increased stem length and diameter, all contribute to increased efficiency of carbohydrate and nutrient absorption to support flowering.

Increased vegetative growth leads to increased flowering, which is reflected in the yield components, resulting in an increased number of pods, an increased number of seeds, and an increased seed weight, thus significantly improving the overall seed yield. This improvement is attributed to a combination of physiological and biochemical factors, with boron playing a crucial role in enhancing yield components and increasing productivity. This is due to boron's essential physiological functions within the plant; it contributes to stimulating flowering and improving pollen viability, which in turn helps increase fruit set, reduce flower drop, and consequently increase the number of pods formed on the plant. Boron helps in the translocation of sugars and nutrients from leaves to growing parts such as pods and seeds. It also contributes to the activation of root growth and nitrogen-fixing bacteria, which positively impacts vegetative growth and increases yield. Among the most important effects of boron application is improved cell wall formation and increased plant tissue strength, helping the plant withstand various environmental conditions and reducing pod deformation. As a result of these effects, the number of flowers and pods per plant increases, along with the number and weight of seeds and the overall plant yield. (Boron plays a role in improving flowering and fruit set by increasing pollen viability and reducing flower drop.) [3, 6, 14].

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