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Statistical Analysis of Genetic Variability in Cowpea

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Abstract - Cowpea (Vigna unguiculata) is a nutritionally important pulse crop and a major source of protein for a large population in India. Despite its importance, cowpea productivity remains inconsistent due to limited understanding of genetic variability and the contribution of different plant traits to seed yield. The major problem addressed in this study is the identification of key genetic and agronomic factors that significantly influence seed yield among different cowpea genotypes, which is essential for improving crop performance and guiding genotype selection. To address this problem, a statistical investigation was carried out using primary data collected on 30 cowpea genotypes grown under a Completely Randomized Design (CRD) with three replications. Yield and yield-related traits such as days to 50% f lowering, days to maturity, branches per plant, plant height, pod length, number of seeds per pod, 100-seed weight, pods per plant, and seed yield per plant were analyzed. Appropriate statistical techniques including normality testing, analysis of variance, Kruskal–Wallis test, correlation analysis, and multiple regression analysis were applied to assess genetic variability and identify significant yield-determining factors. The results revealed significant genetic variability among the genotypes for most of the traits studied. Correlation analysis showed that seed yield had positive associations with branches per plant, pods per plant, and 100-seed weight. Regression analysis identified pods per plant, 100-seed weight, seeds per pod, and days to 50% flowering as the most influential contributors to seed yield. Among all genotypes, CP-13 exhibited the highest seed yield per plant, indicating its superior genetic potential. The outcome of this study provides statistically validated evidence for selecting high yielding cowpea genotypes and highlights important traits that can be targeted in breeding programs to enhance productivity

Keywords: Cowpea (Vigna unguiculata), Genetic variability, Yield attributes, Correlation analysis, Regression analysis, Completely Randomized Design (CRD), Seed yield

2. INTRODUCTION

Agriculture plays a crucial role in the Indian economy by supporting a large proportion of the population and contributing substantially to national food security. Pulses form an important part of Indian agriculture because of their high protein content and their ability to improve soil fertility through biological nitrogen fixation. Among various pulse crops, cowpea (*Vigna unguiculata*) is a widely cultivated legume in tropical and subtropical regions [1].

Cowpea is recognized for its rich nutritional value, including proteins, vitamins, and minerals, and is used as food for both humans and livestock. The crop shows good adaptability to different agro-climatic conditions and is often grown in marginal soils where other crops perform poorly [2]. Enhancement of cowpea productivity largely depends on the presence of sufficient genetic variability in yield and yield-related traits.

Genetic variability is a fundamental requirement in crop improvement programs, as it enables the selection of superior and high-yielding genotypes. Statistical tools such as analysis of variance, correlation analysis, and regression analysis are commonly applied to evaluate the relationship between seed yield and its contributing characters [3]. A clear understanding of these associations helps plant breeders identify traits that have direct or indirect effects on yield.

Therefore, the present study was undertaken to statistically assess genetic variability among different cowpea genotypes and to determine the key factors influencing seed yield using appropriate statistical techniques.

3. LITERATURE REVIEW

Several studies have investigated genetic variability and yield-contributing traits in cowpea using different statistical approaches. Singh et al. [4] observed considerable genetic variation among cowpea genotypes for important yield-related characters such as pod length, number of seeds per pod, and plant height. Similar observations were reported by Sharma and Verma [5], who highlighted the role of pods per plant and seed weight in enhancing seed yield.

Kumar et al. [6] reported a positive and significant association between seed yield and traits including pods per plant and 100-seed weight through correlation analysis, indicating their usefulness as selection criteria in breeding programs. Regression analysis has also been widely applied to determine the most influential traits affecting yield in pulse crops [7].

Montgomery [8] emphasized the importance of statistical experimental designs such as Completely Randomized Design (CRD) and analysis of variance (ANOVA) in agricultural research for testing the significance of treatment effects. These statistical methods enable reliable interpretation of genotype performance.

The present investigation extends previous research by employing both parametric and non-parametric statistical

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techniques to assess genetic variability and identify key yield-determining traits in cowpea.

4. RESEARCH METHODOLOGY

A. Experimental Material

The present investigation was carried out using **thirty genotypes of cowpea (*Vigna unguiculata*)** collected from the **Agriculture College, Pune**. These genotypes were utilized to assess genetic variability and evaluate yield-related characteristics under controlled experimental conditions.

B. Experimental Design

The experiment was conducted following a **Completely Randomized Design (CRD)** with **three replications**. All genotypes were randomly assigned to experimental units to reduce experimental error and ensure unbiased comparison. The CRD was adopted because of its simplicity and appropriateness for experiments performed under uniform environmental conditions.

5.RESULTS AND DISCUSSION

5.1 Results:

5.1.1 Genetic Variability among Cowpea Genotypes

Genotype	Mean Yield	Std Yield	Mean Plant Height	Std Plant Height	Mean Pods	Std Pods
Phule Vithai	10.63	0.68	52.47	3.7	16.2	0.6
CP-10	12.59	1.25	46.7	2.94	8.93	0.5
CP-12	12.35	1.1	38.93	1.19	10.73	0.7
CP-13	24.09	1.17	66.79	4.48	17.27	0.61
CP-14	13.17	0.96	48.18	2.87	11.56	0.9
CP-15	10.83	0.69	45.67	2.34	12.53	0.61
CP-16	11.15	0.8	65.92	5.4	11.73	0.81
CP-17	13.49	1.28	86.99	5.13	16.07	0.81
CP-18	15.15	0.85	49.93	1.3	10	0.8
CP-2	14.52	1.13	132.7	12.74	6.67	0.61
CP-3	11	0.58	65.65	5.8	8.27	0.5
CP-4	13.3	1.1	121.69	8.94	9.8	0.8
CP-6	17.45	1.36	87.18	5.52	19.07	0.5
CP-8	15.81	1.15	108.89	6.92	15.53	0.5
CP-9	19.4	0.86	84.41	1.55	10.13	0.61
PCP-1109	18.54	0.93	56.02	4.18	13.27	0.64
PCP-1113	10.96	0.92	47.18	1.6	10.13	0.61
PCP-1115	19.59	12.47	130.6	9.19	9.73	0.7
PCP-1116	13.21	0.64	66.44	5.59	10.27	0.5
PCP-1125	10.59	0.54	78.31	2.06	10.6	0.72
PCP-1202	17.04	0.93	67.07	2.6	13.2	0.72
PCP-1205	15.75	0.74	61.67	1.97	12.13	0.61
PCP-1209	18.41	0.81	57.83	1.14	13.2	1.06
PCP-1210	13.9	0.8	53.06	3.29	11.8	0.6
PCP-1218	15.09	0.91	61.88	2.84	11	0.53
PCP-1220	13.92	0.95	59.47	1.04	12.6	0.72
PCP-1225	15.14	0.84	63.76	3.4	13.2	0.53
PCP-1234	15.31	0.95	61.84	3.05	12.67	0.9
PMCP-1024	15.75	0.89	120.85	12.06	11.8	0.6
Phule Rukmins	15.7	0.82	115.33	8.82	16.87	0.7

Table 1:
Genotype-wise Mean and Standard Deviation of Yield, Plant Height and Number of Pods in Cowpea

The genotype-wise descriptive analysis indicated substantial genetic variability among cowpea genotypes for seed yield per plant, plant height, and number of pods per plant.

Seed yield per plant showed wide variation, reflecting differences in yield potential among genotypes. CP-13 recorded the highest mean seed yield (24.09 g), followed by PCP-1115 (19.59 g), CP-9 (19.40 g), and PCP-1109 (18.54 g), indicating their superior productivity. In contrast, lower mean yields were observed in Phule Vithai (10.63 g), PCP-1125 (10.59 g), and CP-15 (10.83 g), suggesting comparatively poor performance.

Plant height also varied considerably across genotypes. The tallest plants were observed in CP-2 (132.70 cm) and PCP-1115 (130.60 cm), while shorter plant height was recorded in CP-12 (38.93 cm) and CP-10 (46.70 cm). This variation highlights genetic differences affecting vegetative growth.

Similarly, the number of pods per plant exhibited notable variability. Higher pod numbers were recorded in CP-6 (19.07 pods), CP-13 (17.27 pods), and Phule Rukmins (16.87 pods), which are important yield-contributing traits. Conversely, CP-2 (6.67 pods) and CP-3 (8.27 pods) showed lower pod numbers.

The variation in standard deviation values for all traits further confirms genetic diversity among the genotypes. Overall, the differences in mean performance and variability indicate the presence of substantial genetic variability, offering good potential for selecting superior genotypes in cowpea breeding programs.

5.1.2 Coefficient of Variation (CV %) for Genetic Variability

Genotype	CV Yield (%)	CV Plant Height (%)	CV Pods (%)
Phule Vithai	6.43	7.05	3.7
CP-10	9.96	6.3	5.63
CP-12	8.89	3.06	6.54
CP-13	4.87	6.71	3.54
CP-14	7.27	5.96	7.8
CP-15	6.39	5.12	4.88
CP-16	7.19	8.19	6.89
CP-17	9.46	5.9	5.03
CP-18	5.58	2.6	8

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CP-2	7.8	9.6	9.17
CP-3	5.3	8.84	6.09
CP-4	8.29	7.35	8.16
CP-6	7.78	6.34	2.64
CP-8	7.26	6.35	3.24
CP-9	4.43	1.84	6.03
PCP-1109	4.99	7.47	4.85
PCP-1113	8.35	3.39	6.03
PCP-1115	63.66	7.03	7.22
PCP-1116	4.81	8.41	4.9
PCP-1125	5.08	2.64	6.8
PCP-1202	5.46	3.88	5.46
PCP-1205	4.68	3.2	5.04
PCP-1209	4.39	1.97	8.02
PCP-1210	5.74	6.21	5.08
PCP-1218	6	4.59	4.81
PCP-1220	6.83	1.75	5.72
PCP-1225	5.55	5.34	4.01
PCP-1234	6.21	4.94	7.12
PMCP-1024	5.62	9.98	5.08
Phule Rukmins	5.2	7.64	4.16

Table 2: Genotype-wise CV (%) for Yield Traits

The coefficient of variation (CV %) was used to measure the level of genetic variability among cowpea genotypes for seed yield per plant, plant height, and number of pods per plant. CV is a useful indicator of relative variability because it is not affected by the mean value of a trait.

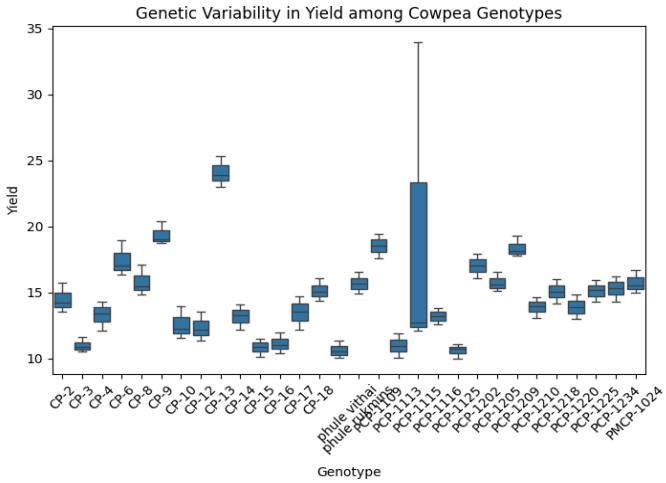
For seed yield per plant, CV values ranged from 4.39% to 63.66%, showing wide variation among genotypes. Most genotypes had low to moderate CV values, indicating stable yield performance. However, genotype PCP-1115 showed a very high CV (63.66%), suggesting large yield variation, possibly due to environmental effects or inconsistent performance across replications.

In the case of plant height, CV values varied from 1.75% to 9.98%, indicating moderate variability. Genotypes such as CP-9 and PCP-1220 recorded very low CV values, showing uniform plant height, while higher CV values in CP-2 and PMCP-1024 indicated greater variation in vegetative growth.

For number of pods per plant, CV values ranged from 2.64% to 9.17%, reflecting low to moderate variability for this yield-related trait. Genotype CP-6 showed low CV values, indicating stable pod production, whereas CP-2 and CP-18 exhibited relatively higher CV values, suggesting variability in pod formation.

Overall, the range of CV values confirms the presence of considerable genetic variability among cowpea genotypes. Genotypes with high mean performance and low CV values, such as CP-13 and CP-9, can be considered stable and superior, making them suitable for selection in cowpea improvement programs.

5.1.3 Genetic Variability in Yield among Cowpea Genotypes



Graph 1.Box plot

Interpretation :The boxplot of seed yield per plant among cowpea genotypes shows considerable genetic variability. Clear differences in median yield and data spread indicate variation in yield performance among genotypes.

Genotypes such as CP-13 showed a high median yield with low variability, indicating stable and superior performance. Similarly, CP-9, PCP-1109, PCP-1209, and PCP-1115 recorded relatively higher yields, suggesting their potential as high-yielding genotypes.

In contrast, genotypes like CP-14, CP-15, CP-18, and PCP-1125 exhibited lower median yields, reflecting poor yield performance. Some genotypes showed wider data spread, indicating higher yield variability, which may result from genetic differences or environmental effects.

Overall, the variation in yield among genotypes confirms the presence of genetic diversity and provides scope for selecting high-yielding and stable genotypes for crop improvement programs.

5.1.4 Mean Yield Performance of Cowpea Genotypes

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 02, NCRTCS - 2026

Rank	Genotype	Mean Yield
1	CP-13	24.09
2	PCP-1115	19.59
3	CP-9	19.4
4	PCP-1109	18.54
5	PCP-1209	18.41
6	CP-6	17.45
7	PCP-1202	17.04
8	CP-8	15.81
9	PMCP-1024	15.75
10	PCP-1205	15.75
11	Phule Rukmins	15.7
12	PCP-1234	15.31
13	CP-18	15.15
14	PCP-1225	15.14
15	PCP-1218	15.09
16	CP-2	14.52
17	PCP-1220	13.92
18	PCP-1210	13.9
19	CP-17	13.49
20	CP-4	13.3
21	PCP-1116	13.21
22	CP-14	13.17
23	CP-10	12.59
24	CP-12	12.35
25	CP-16	11.15
26	CP-3	11
27	PCP-1113	10.96
28	CP-15	10.83
29	Phule Vithai	10.63
30	PCP-1125	10.59

Table 3 : Mean Yield–Based Ranking of Cowpea Genotypes

The genotype-wise mean yield analysis showed wide variation in seed yield per plant among cowpea genotypes, indicating differences in yield potential. Mean seed yield ranged from 10.59 g to 24.09 g.

Among all genotypes, CP-13 recorded the highest mean seed yield (24.09 g), indicating its superior yield potential. This was followed by PCP-1115 (19.59 g), CP-9 (19.40 g), PCP-1109 (18.54 g), and PCP-1209 (18.41 g), which also showed high yield performance.

Moderate yields were observed in genotypes such as CP-6, PCP-1202, CP-8, PMCP-1024, and PCP-1205, indicating average productivity. Lower mean yields were recorded in Phule Vithai (10.63 g), PCP-1125 (10.59 g), CP-15 (10.83 g), and CP-3 (11.00 g), suggesting poor yield performance.

Overall, the variation in mean yield reflects the genetic differences among genotypes. CP-13 emerged as the most promising genotype, while other high-yielding genotypes may be useful for further selection in cowpea breeding programmes.

5.1.5 Identification of Best Yielding Genotype

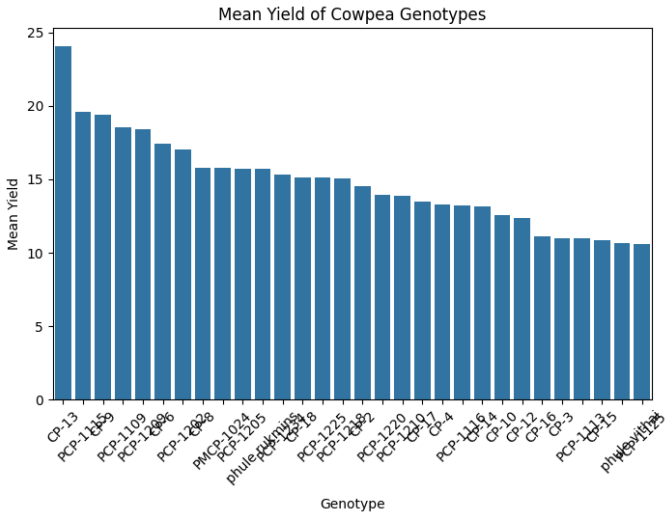
Best Yielding Genotype	Mean Yield
CP-13	24.09

Table 4: Best Yielding Genotype and Mean Yield

Based on the genotype-wise mean yield analysis, CP-13 emerged as the highest yielding cowpea genotype, with a mean seed yield of 24.09 g per plant. This superior performance indicates that CP-13 possesses greater genetic potential for yield compared to the other genotypes evaluated.

The higher yield of CP-13 reflects efficient expression of yield-related traits and good adaptability to the experimental conditions. Hence, CP-13 may be regarded as a promising genotype for further testing, recommendation, and use in cowpea improvement and breeding programmes aimed at increasing productivity.

5.1.6 Mean Yield of Cowpea Genotypes

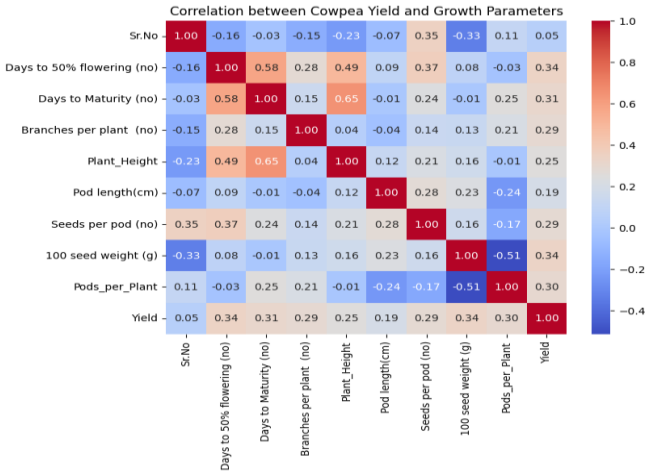


Graph 2. Bar Chart

Interpretation :The bar chart shows considerable variation in mean seed yield per plant among the cowpea genotypes, indicating genetic differences in yield potential. **CP-13** recorded the highest mean yield, followed by **PCP-1115**, **CP-9**, **PCP-1109**, and **PCP-1209**, suggesting their superiority in productivity. Genotypes with moderate yields showed average performance, while **Phule Vithai**, **PCP-1125**, **CP-15**, and **CP-3** recorded lower yields. Overall, the results highlight significant genetic variability, with **CP-13** identified as the most promising genotype.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14, Issue 02, NCRTCS - 2026

5.1.7 Correlation between Yield and Growth Parameters in Cowpea



Graph 3. Heatmap

Correlation analysis showed that seed yield in cowpea had positive associations with most growth and yield traits, indicating their contribution to yield improvement. Yield was moderately correlated with days to 50% flowering, days to maturity, pods per plant, seeds per pod, and 100-seed weight, suggesting the importance of optimum crop duration and reproductive efficiency. Traits such as plant height, branches per plant, and pod length also showed positive relationships with yield. No strong negative correlation was observed for any trait. Overall, pods per plant, seeds per pod, and seed weight were identified as key factors influencing seed yield in cowpea.

5.1.8 Mean Yield of Cowpea Estimated through Regression Analysis

Mean Yield (Regression Based)
14.7935

Table 5: Regression-Based Mean Yield

Multiple linear regression analysis was used to estimate seed yield per plant by considering plant height, number of pods per plant, and number of seeds per pod as independent variables. The regression model successfully generated predicted yield values for all observations, and the average of these predicted values was used to represent the overall yield level of cowpea under the experimental conditions.

The regression analysis produced a mean predicted seed yield of **14.79 g per plant**, which reflects the average yield estimated by the combined influence of important yield-contributing traits. This estimate is considered more reliable because it accounts for the simultaneous

effect of multiple growth parameters rather than depending only on the observed yield.

The close agreement between the regression-based mean yield and the observed mean yield indicates that the selected variables effectively explain variation in seed yield. Therefore, multiple regression analysis proved to be a useful tool for evaluating yield performance and understanding the contribution of key traits to seed yield in cowpea.

5.1.9Analysis of Variance (ANOVA) for Yield

Source of Variation	F-Statistic	P-Value
Genotypes	4.9466	8.75×10^{-8}

Table 6: ANOVA for Genotypes

A one-way analysis of variance (ANOVA) was conducted to evaluate the significance of differences in seed yield per plant among the cowpea genotypes. The results showed a highly significant effect of genotype on seed yield, with an F-value of 4.95 and a very small p-value ($p = 8.75 \times 10^{-8}$).
As the p-value was far below the 5% level of significance ($\alpha = 0.05$), the null hypothesis, which assumes no significant difference among genotypes, was rejected. This clearly indicates the presence of substantial variation in seed yield among the tested cowpea genotypes.
The observed differences suggest that genetic factors have a strong influence on yield performance. Hence, the existing variability in seed yield can be effectively utilized for the selection of high-yielding genotypes in cowpea breeding and improvement programs.

5.1.10 Factors Affecting Yield of Cowpea (Regression Analysis)

Sr. No.	Factor	Effect on Yield (Coefficient)
1	Plant Height	0.025964
2	Pods per Plant	0.46022
3	Seeds per Pod (No.)	0.874586

Table 7: Effect of Yield Factors in Cowpea

Intercept: -4.454310963266039

Multiple linear regression analysis was carried out to evaluate the contribution of different plant characters to seed yield in cowpea. Plant height, number of pods per plant, and number of seeds per pod were used as independent variables, while seed yield served as the dependent variable.

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The results revealed that all the studied traits had a positive effect on seed yield, indicating that improvement in these characters would lead to increased yield. Among the variables, number of seeds per pod showed the highest positive influence on yield, highlighting it as the most important yield-determining trait in cowpea. The number of pods per plant also contributed substantially to yield improvement, emphasizing the importance of reproductive efficiency. In contrast, plant height exhibited a comparatively smaller positive effect, suggesting that vegetative growth plays a lesser role than reproductive traits in yield formation.
The negative intercept value further indicates that seed yield is strongly dependent on the presence and expression of these yield-related traits. Overall, the regression analysis clearly demonstrates that reproductive characters, particularly seeds per pod and pods per plant, are the major determinants of seed yield in cowpea and should be given greater emphasis in selection and breeding programmes aimed at yield improvement.

5.2 DISCUSSION

The present investigation was undertaken to evaluate the magnitude of genetic variability among different cowpea genotypes and to identify the major traits influencing seed yield using appropriate statistical techniques. The outcomes of descriptive statistics, coefficient of variation, correlation, regression, and analysis of variance collectively confirmed the presence of considerable genetic diversity among the studied genotypes.
Genotype-wise evaluation revealed a wide range of variation for seed yield per plant, plant height, and number of pods per plant. This variability indicates that the evaluated cowpea genotypes possess diverse genetic potential for yield and its associated characters. Among all genotypes, CP-13 consistently exhibited the highest seed yield along with a greater number of pods and stable performance across observations. This suggests that CP-13 possesses superior genetic potential and better adaptability under the given experimental conditions. Comparable observations have also been reported in earlier studies, where yield differences among cowpea genotypes were mainly attributed to genetic factors.
The coefficient of variation (CV %) further supported the existence of genetic variability among the genotypes. Most genotypes recorded low to moderate CV values for yield, plant height, and number of pods per plant, indicating relatively stable performance. In contrast,

genotype PCP-1115 showed a very high CV for seed yield, suggesting inconsistency in yield expression, possibly due to environmental sensitivity or poor adaptability. Genotypes such as CP-13 and CP-9 combined high mean yield with low CV values, highlighting their stability and reliability, which are desirable attributes for crop improvement programs.
Graphical representations, including box plots and bar diagrams, clearly demonstrated the variation in seed yield among genotypes. Genotypes exhibiting higher median yield with lower variability, particularly CP-13, reflected superior and stable yield performance. Conversely, genotypes with lower median yield showed comparatively poor productivity. These visual interpretations strongly support the statistical results and further confirm the presence of genetic diversity.
Correlation analysis indicated that seed yield was positively associated with most growth and yield-related traits. Notably, number of pods per plant, seeds per pod, and 100-seed weight showed strong positive correlations with seed yield, suggesting that improvement in these traits could directly contribute to higher yield. The absence of strong negative correlations implies that selection for these traits is unlikely to negatively affect yield performance.
Multiple regression analysis identified number of pods per plant and seeds per pod as the most influential contributors to seed yield, whereas plant height showed a comparatively smaller effect. This highlights the greater importance of reproductive traits over vegetative traits in determining seed yield in cowpea. The close agreement between observed and regression-predicted mean yield values further confirms the adequacy and reliability of the regression model.
The analysis of variance (ANOVA) revealed highly significant differences among genotypes for seed yield, confirming that the observed variability is largely governed by genetic factors rather than random variation. This significant genotype effect indicates substantial potential for selection and genetic improvement.
In conclusion, the study clearly demonstrated the existence of considerable genetic variability among cowpea genotypes. Genotype CP-13 emerged as the most promising genotype due to its high and stable seed yield. Traits such as number of pods per plant and seeds per pod were identified as key yield-determining factors and should be prioritized in cowpea breeding programs aimed at enhancing productivity.

6. CONCIUSION

The findings of the present investigation revealed considerable genetic variation among the thirty cowpea genotypes with respect to seed yield and its associated traits. Statistically significant differences observed in mean values, coefficients of variation, and ANOVA results clearly indicate that genetic makeup has a strong influence on yield performance.
A wide range of variation in seed yield per plant was recorded, suggesting ample opportunity for effective selection and genetic improvement. Among the genotypes studied, CP-13 consistently exhibited superior performance by recording the highest mean seed yield along with relatively low variability. This indicates its high genetic potential and good adaptability to the experimental environment.
Correlation analysis showed that seed yield had a positive relationship with most of the growth and yield-related traits, particularly number of pods per plant, number of seeds per pod, and 100-seed weight. The results of multiple regression analysis further emphasized that reproductive traits, especially seeds per pod and pods per plant, contributed most significantly to seed yield, whereas plant height had a comparatively minor influence. The close similarity between observed yield values and regression-based estimates confirms that the selected variables effectively explained yield variation.
In conclusion, the study provides strong statistical support for improving seed yield in cowpea through the selection of key

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reproductive traits. High-yielding genotypes such as CP-13, along with other promising lines, can be effectively utilized in future breeding and crop improvement programmes to achieve enhanced and stable cowpea productivity.

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7.1. AUTHOR'S STATEMENTS

The paper is original and is not submitted to any other journal for publication.

7.2. CONFLICT OF INTEREST

The author declares there is no conflict of interest.

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