

ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2026): 4.97
IJAFS 2026; 8(11): 167-170
www.agriculturaljournals.com
Received: 23-09-2026
Accepted: 25-10-2026
Published: 04-11-2026

Nahid Parveen
M.Sc. Student, Department of Agril. Botany, Govt. College of Agriculture, Pune, Maharashtra, India

DB Lad
Professor of Agricultural Botany, ZARS, Ganeshkhind, Pune, Maharashtra, India

AA Bhagat
Assistant Professor, Division of Statistics, Govt. College of Agriculture, Pune, Maharashtra, India

Srikanth Banoth
M.Sc. Student, Department of Agril. Botany, Govt. College of Agriculture, Pune, Maharashtra, India

AB Rajguru
Associate Professor of Agricultural Botany, ARS Kasbe, Digraj, Dist. Sangli, Maharashtra, India

Corresponding Author:
Nahid Parveen
M.Sc. Student, Department of Agril. Botany, Govt. College of Agriculture, Pune, Maharashtra, India

Character association and path coefficient analysis for seed yield, protein, iron and zinc in chickpea (*Cicer arietinum* L.)

Nahid Parveen[1], DB Lad[2], AA Bhagat[3], Srikanth Banoth[4], AB Rajguru[5]

DOI: https://www.doi.org/10.33545/2664844X.2026.v8.i11c.90089

Abstract
Selection for seed yield is more effective when it targets the characters that are genetically tied to yield, and when yield improvement does not cost seed protein, iron (Fe) or zinc (Zn). Genotypic correlations and path coefficients of 12 characters with yield per plant were worked out in 36 chickpea genotypes grown in a randomized block design with three replications. Yield per plant was positively and significantly associated with seeds per pod (r = 0.983) and pods per plant (r = 0.928), negatively with 100-seed weight (r = −0.875), and positively with plant spread (r = 0.405, significant at 5%). Association with days to flowering and maturity, plant height, branches and protein was not significant. Fe (r = −0.107) and Zn (r = −0.283) were not significantly associated with yield, and Fe and Zn were positively associated with each other (r = 0.653). Pods per plant had the largest direct effect on yield (6.016), followed by 100-seed weight (2.220) and days to 50% flowering (1.113); seeds per pod had a large negative direct effect (−3.943) although its correlation was the strongest positive one, and the residual effect was 0.316. Because pods per plant, seeds per pod and seed weight are strongly inter-correlated (|r| = 0.95–0.98), the path coefficients exceed unity and should be read as indicative. The associations involving Fe and Zn were also influenced by RVG-202, as the correlation between Fe and Zn decreased from 0.65 to 0.21 when this genotype was excluded. Overall, pods per plant emerged as a useful selection criterion for improving seed yield in the studied material. The results also indicate potential for improving seed yield alongside Fe, Zn and protein content, providing a basis for developing nutritionally superior chickpea genotypes.

Keywords: Chickpea, correlation, path analysis, direct effect, seed yield, iron, zinc, protein

1. Introduction

Yield in chickpea is a product of several components, and many of them are correlated with each other. A correlation coefficient shows how closely two characters move together, but it cannot say whether the link is direct or runs through a third character. Path coefficient analysis (Wright, 1921; Dewey *et al.*, 1959) [2, 1] splits a correlation into a direct effect and indirect effects through other characters, so breeders can decide which characters deserve selection pressure.

Biofortification adds a second question. If seed Fe, Zn and protein are negatively associated with yield, improving their concentrations may compromise yield, and the breeding strategy has to change. Previous studies in chickpea have reported varying associations between yield components and seed nutritional traits (Diapari *et al.*, 2014; Upadhyaya *et al.*, 2016; Samineni *et al.*, 2022; Idrissi *et al.*, 2024) [3, 4, 5], although these relationships may differ among genetic materials and environments.

The present study estimates the genotypic correlations among 13 characters, including seed protein, Fe and Zn, in 36 chickpea genotypes, and partitions the correlation of each of 12 characters with seed yield per plant into direct and indirect effects. It also examines the interrelationships among the traits to assess the reliability of the path analysis, since strong correlations among explanatory characters can affect the interpretation of path coefficients (Dewey *et al.*, 1959) [1].

2. Materials and Methods

2.1 Experimental material

The panel comprised 36 chickpea genotypes, including 33 advanced breeding lines and three checks (Phule Vikram, Phule Vikrant and RVG-202). The field experiment was conducted at the Zonal Agricultural Research Station (ZARS), Ganeshkhind, Pune, during the Rabi season of 2025. The genotypes were evaluated in a randomized block design (RBD) with three replications. Each plot was 4 m long, with a spacing of 30 cm between rows and 10 cm between plants. All recommended agronomic and crop management prac

2664844X.2026.v8.i11c.90089 by International Journal of Agriculture and Food Science on [04/11/2026]. See the Terms and Conditions (https://www.agriculturaljournals.com) for rules of use; OA articles are governed by the applicable Creative Commons License

tices were followed throughout the growing season to ensure healthy crop growth and proper crop establishment.

2.2 Characters

The characters studied were days to 50% flowering (DFF), days to maturity (DM), plant height (PH), plant spread (PS), primary branches (NPB), secondary branches (NSB), pods per plant (NPP), seeds per pod (NSP), 100-seed weight (HSW), Protein % (P%), seed Fe and seed Zn, with yield per plant (YP) as the dependent character. Seed protein content was estimated using near-infrared reflectance spectroscopy (NIRS), while Fe and Zn contents were determined by atomic absorption spectrophotometry (AAS).

2.3 Statistical analysis

Genotypic and phenotypic correlation coefficients were calculated from the variance and covariance components of the analysis of variance (Johnson *et al.*, 1955) [6]. Genotypic correlations were tested against the tabulated correlation coefficient at $n - 2 = 34$ degrees of freedom (r = 0.329 at 5% and 0.424 at 1%). Path coefficient analysis followed Dewey *et al.* (1959) [1]: the direct effects (P) were obtained by solving the normal equations R·P = r, where R is the matrix of genotypic correlations among the 12 independent characters and r is the vector of their correlations with yield. The indirect effect of character i through character j is $r_{ij} \times P_j$. The residual effect was $\sqrt{1 - \sum P(i) \cdot r(iy)}$. To judge how stable the coefficients were, the variance inflation factor (VIF) was computed for each independent character, and the correlations were recalculated on genotype means with and without RVG-202.

3. Results

3.1 Association of characters with yield per plant

Genotypic correlations are given in Table 1. Yield per plant was highly significantly and positively correlated with seeds per pod (0.983) and pods per plant (0.928), and highly significantly and negatively correlated with 100-seed weight (−0.875). Plant spread showed a positive association with yield (0.405) that was significant at 5%. Days to 50% flowering (0.256), secondary branches (0.227), primary branches (0.196), protein (0.151), plant height (0.107) and days to maturity (0.099) were positively but not significantly associated with yield, while Fe (−0.107) and Zn (−0.283) were negatively and non-significantly associated with it.

Table 1. Genotypic correlation coefficients among 13 characters in 36 chickpea genotypes (YP = yield per plant)

Trait	DM	PH	PS	NPB	NSB	NPP	NSP	HSW	P%	Fe	Zn	YP
DFF	0.655**	0.307	0.023	-0.117	0.037	0.292	0.257	-0.320	-0.040	-0.203	0.175	0.256
DM		0.231	0.493**	-0.275	0.117	0.078	0.067	-0.064	0.012	0.157	0.399*	0.099
PH			0.632**	0.529**	0.535**	0.165	0.153	-0.245	0.042	0.101	0.336*	0.107
PS				0.089	0.522**	0.428**	0.352*	-0.424**	0.065	0.542**	0.568**	0.405*
NPB					0.430**	0.236	0.270	-0.301	0.115	-0.207	-0.173	0.196
NSB						0.152	0.266	-0.183	0.030	-0.048	0.058	0.227
NPP							0.970**	-0.984**	0.015	-0.101	-0.191	0.928**
NSP								-0.952**	0.218	-0.176	-0.324	0.983**
HSW									-0.044	0.164	0.176	-0.875**
P%										-0.183	-0.160	0.151
Fe											0.653**	-0.107
Zn												-0.283

* and ** significant at 5% ($r \geq 0.329$) and 1% ($r \geq 0.424$), respectively. DFF = days to 50% flowering, DM = days to maturity, PH = plant height, PS = plant spread, NPB = primary branches, NSB = secondary branches, NPP = pods per plant, NSP = seeds per pod, HSW = 100-seed weight, P% = protein %, Fe = iron, Zn = zinc.

3.2 Inter-relationships among characters

Days to 50% flowering was strongly associated with days to maturity (0.655). Plant height was associated with plant spread (0.632), primary branches (0.529) and secondary branches (0.535), and plant spread with secondary branches (0.522). Pods per plant and seeds per pod were almost perfectly correlated (0.970), and both were almost perfectly and negatively correlated with 100-seed weight (−0.984 and −0.952): genotypes with many pods and seeds per pod had small seeds. Protein was weakly associated with all other characters ($|r| \leq 0.218$).

Fe and Zn were strongly and positively correlated (0.653), and both were positively correlated with plant spread (0.542 and 0.568). Zn was also correlated with days to maturity (0.399, 5%) and plant height (0.336, 5%). Neither mineral was significantly correlated with pods per plant, seeds per pod or seed weight.

3.3 Path analysis

Direct and indirect effects on yield per plant are given in Table 2, and the residual effect was 0.316 (R^2 = 0.90). Pods per plant had by far the largest positive direct effect (6.016), followed by 100-seed weight (2.220), days to 50% flowering (1.113), plant spread (0.968), protein (0.864), secondary branches (0.608), primary branches (0.273) and Fe (0.261). Seeds per pod (−3.943), Zn (−1.081), plant height (−0.720) and days to maturity (−0.616) had negative direct effects.

The correlation of pods per plant with yield (0.928) was in line with its direct effect (6.016), but 5.836 of the correlation of seeds per pod with yield (0.983) came from the indirect effect through pods per plant, against a direct effect of −3.943. The negative correlation of 100-seed weight with yield (−0.875) hides a positive direct effect (2.220) that is cancelled by a large negative indirect effect through pods per plant (−5.918) and a positive one through seeds per pod (3.753). Plant spread, with a direct effect of 0.968, had its positive correlation with yield (0.405) cut down by negative indirect effects through seeds per pod (−1.388) and seed weight (−0.942), but raised by the indirect effect through pods per plant (2.574).

For Fe, a small positive direct effect (0.261) was offset by negative indirect effects, mainly through Zn (−0.706) and pods per plant (−0.606), leaving an overall correlation of −0.107. For Zn, a negative direct effect (−1.081) was partly compensated by positive indirect effects through seeds per pod (1.278) and plant spread (0.550).

2664845X, 2026, 8(1), Downloaded from https://www.doi.org/10.33545/2664845X.2026.v8.i1c.90089 by International Journal of Agriculture and Food Science on [04/11/2026]. See the Terms and Conditions (https://www.agriculturaljournals.com) for rules of use; OA articles are governed by the applicable Creative Commons License

Table 2. Direct (bold, diagonal) and indirect effects of 12 characters on yield per plant in chickpea; each row shows the effect of the row character acting through the column character

Trait	DFF	DM	PH	PS	NPB	NSB	NPP	NSP	HSW	P%	Fe	Zn	r with YP
DFF	1.113	-0.403	-0.221	0.023	-0.032	0.022	1.753	-1.012	-0.710	-0.035	-0.053	-0.189	0.256
DM	0.728	-0.616	-0.166	0.477	-0.075	0.071	0.468	-0.266	-0.143	0.011	0.041	-0.431	0.099
PH	0.341	-0.142	-0.720	0.611	0.144	0.326	0.993	-0.602	-0.544	0.037	0.026	-0.363	0.107
PS	0.026	-0.304	-0.455	0.968	0.024	0.318	2.574	-1.388	-0.942	0.057	0.142	-0.614	0.405*
NPB	-0.130	0.169	-0.381	0.086	0.273	0.262	1.418	-1.065	-0.669	0.099	-0.054	0.187	0.196
NSB	0.041	-0.072	-0.386	0.506	0.117	0.608	0.917	-1.048	-0.406	0.026	-0.013	-0.063	0.227
NPP	0.324	-0.048	-0.119	0.414	0.064	0.093	6.016	-3.825	-2.184	0.013	-0.026	0.207	0.928**
NSP	0.286	-0.042	-0.110	0.341	0.074	0.162	5.836	-3.943	-2.113	0.188	-0.046	0.351	0.983**
HSW	-0.356	0.040	0.177	-0.411	-0.082	-0.111	-5.918	3.753	2.220	-0.038	0.043	-0.191	-0.875**
P%	-0.045	-0.008	-0.030	0.063	0.031	0.018	0.088	-0.857	-0.098	0.864	-0.048	0.173	0.151
Fe	-0.225	-0.097	-0.073	0.524	-0.056	-0.029	-0.606	0.694	0.364	-0.159	0.261	-0.706	-0.107
Zn	0.195	-0.246	-0.242	0.550	-0.047	0.036	-1.149	1.278	0.392	-0.138	0.171	-1.081	-0.283

Residual effect = 0.316. Row sums of the direct and indirect effects equal the genotypic correlation with yield (rounding aside). * and ** as in Table 1.

3.4 Stability of the associations

The three yield components were strongly inter-correlated, and on genotype means the VIF was 33.2 for pods per plant, 32.1 for 100-seed weight and 6.0 for seeds per pod, against 1.3–3.4 for the other nine characters. Recorded yield per plant also matched the product of pods per plant, seeds per pod and 100-seed weight divided by 100 closely (r = 0.993 across the 36 genotypes).

The association of the minerals with other characters depended on RVG-202, which had the highest Fe, Zn and plant spread. On genotype means, the Fe–Zn correlation was 0.65 with RVG-202 and 0.21 without it; the Zn–yield correlation went from −0.27 to −0.01, the Fe–yield correlation from −0.10 to 0.17, and the Fe–plant spread and Zn–plant spread correlations from 0.40 and 0.42 to 0.19 and 0.17. Correlations among yield components were unaffected (pods per plant and yield 0.88 and 0.87; seeds per pod and yield 0.96 with and without; seed weight and yield −0.82 and −0.81).

4. Discussion

4.1 Yield components

The strong, positive association of yield with pods per plant and seeds per pod, and the negative association with seed weight, indicate a possible compensatory relationship among yield components in chickpea. Similar relationships among yield components have been reported in chickpea, although their strength may vary across genotypes and environments (Dewey *et al.*, 1959; Diapari *et al.*, 2014; Samineni *et al.*, 2022) [1, 3, 5]. In the present panel, the negative association between pods per plant and 100-seed weight was particularly strong (r = -0.984). Because seed yield is influenced by the number of pods, seeds per pod and seed weight, part of the strong association between these components and yield may reflect their contribution to yield formation rather than independent genetic relationships. The results therefore suggest that, within the evaluated genotypes, pod number and seeds per pod were more important in distinguishing high-yielding genotypes than seed size. The highest-yielding genotypes (Phule G-231137, Phule G-1724-1-8 and TRCH-2) had medium-to-small seeds and a high number of pods, whereas C-2345 and RVG-202, which had relatively large seeds, were among the lower-yielding genotypes.

The number of branches, plant height, days to flowering and days to maturity were not significantly associated with yield. Plant spread showed a positive association with yield that was significant at the 5% level (r = 0.405). This suggests that plant spread may have some relevance to yield performance in the present material, although the association should be validated across additional seasons and environments. Similar studies of chickpea have reported variation in the relationships between yield and its component traits, highlighting the importance of evaluating these associations within the target breeding material (Chopdar *et al.*, 2017; Umashankar *et al.*, 2022; Samineni *et al.*, 2022) [7, 8, 5].

4.2 Direct and indirect effects

Pods per plant combined a high correlation with a large direct effect, so its association with yield is real rather than a result of indirect effects, and selection on pods per plant should be effective. The large negative direct effect of seeds per pod (−3.943), against the strongest positive correlation, means its correlation with yield is carried almost entirely by pods per plant (5.836). This is the situation in which, as Dewey *et al.* (1959) [1] and later authors have noted, indirect causal factors have to be considered, and selection should then be based on the character that carries the direct effect, here pods per plant. The same reasoning applies to 100-seed weight, whose positive direct effect (2.220) is overridden by its negative link with pod number.

Several path coefficients, including 6.016, −3.943 and 2.220, were large in magnitude, with some exceeding unity. Such values can occur when independent characters are strongly inter-correlated, making individual path coefficients unstable and difficult to interpret. This concern was supported by variance inflation factor (VIF) values above 30 for pods per plant and 100-seed weight. Multicollinearity can inflate coefficient estimates and cause their signs and magnitudes to change with relatively small changes in the data (Graham, 2003) [9]. Therefore, although pod number appears to be an important trait in this panel, the exact magnitudes of the direct effects for seeds per pod and 100-seed weight should be interpreted cautiously.

The residual effect of 0.316 indicates that the characters included in the path analysis accounted for approximately 90% of the variation in seed yield per plant, based on the coefficient of determination ($R^2 = 1 - 0.316^2 \approx 0.900$). This relatively high proportion may partly reflect the close mathematical relationship between yield and its component traits. To assess the robustness of these findings, further analysis using a reduced set of less strongly correlated predictors or ridge path analysis could be considered (Graham, 2003) [9]

4.3 Seed protein, iron and zinc

Protein was nearly independent of yield and of other characters, which suggesting that it may be possible to improve protein content without substantially affecting yield. However, the relatively low variability observed for protein content in the present material may limit the expected response to selection (Johnson *et al.*, 1955; Samineni *et al.*, 2022) [6, 5]. Fe and Zn were not significantly correlated with yield, so no significant yield penalty was found for improving them. as it suggests that improving grain mineral concentrations may be possible without an apparent yield penalty. Similar studies have highlighted the potential for improving the nutritional quality of chickpea through the selection of genotypes with higher seed mi

2664844X, 2026, 8(1), Downloaded from https://www.doi.org/10.33545/2664844X.2026.v8.i1i.90089 by International Journal of Agriculture and Food Science on [04/11/2026]. See the Terms and Conditions (https://www.agriculturaljournals.com) for rules of use; OA articles are governed by the applicable Creative Commons License

cronutrient concentrations (Upadhyaya *et al.*, 2016; Grewal *et al.*, 2020; Idrissi *et al.*, 2024) [4, 10].

The positive Fe–Zn correlation (0.653) is a common finding and suggests that the two minerals might be improved together. Positive associations between grain Fe and Zn have also been reported in chickpea germplasm (Diapari *et al.*, 2014; Upadhyaya *et al.*, 2016; Samineni *et al.*, 2022) [3, 4, 5]. However, in the present study, it largely depends on one genotype: without RVG-202 the correlation on means falls to 0.21 and is not significant, and the same applies to the links of Fe and Zn with plant spread and maturity. RVG-202 is a late, low-yielding check with large seeds and a wide canopy, so its high mineral content may be a feature of this genotype rather than a general relation between minerals and plant type. Joint selection for Fe and Zn would therefore need confirmation in a larger set, and the apparent association with plant spread should not be used as an indirect selection criterion.

4.4 Implications for selection

Pods per plant emerged as an important selection criterion for improving seed yield in the evaluated chickpea genotypes. Seed weight should also be included during selection, since pushing pod number up reduces seed size, and the best balance may be an intermediate seed size with high pod number. Seed Fe, Zn and protein content showed no significant negative association with yield, suggesting potential for improving nutritional quality without a substantial yield penalty in this panel. However, the positive association between Fe and Zn was strongly influenced by RVG-202 and was weak after its exclusion. Phule G-231137, which recorded the highest seed yield along with 120 ppm Fe, may be a promising parent for combining high yield with improved grain iron content. Further evaluation across environments is needed to confirm the stability of these traits and associations.

4.5 Limitations

The study identified useful relationships among yield components and grain nutritional traits in the evaluated chickpea genotypes. As the experiment was conducted at one location during one season, further evaluation across environments would help establish the consistency of these associations. The path coefficients provide useful preliminary insights into direct and indirect effects, although interrelationships among traits may influence individual estimates. Future studies using multi-environment data and a carefully selected set of less strongly correlated traits could further strengthen these findings and support their application in chickpea improvement.

5. Conclusions

Seed yield per plant was significantly and positively associated with pods per plant and seeds per pod, but negatively associated with 100-seed weight. Pods per plant showed the highest positive direct effect on yield, indicating its potential as a useful selection criterion, while the effects of seeds per pod and seed weight were influenced by their relationships with other yield components. Seed Fe, Zn and protein contents were not significantly associated with yield, suggesting that nutritional quality could be improved with little expected yield penalty in the evaluated material. However, the positive association between Fe and Zn was strongly influenced by RVG-202 and requires further validation before joint selection. As multicollinearity may affect the stability of individual path coefficients, further analysis using plot-wise data and a reduced set of predictors or ridge path analysis is recommended to confirm these findings.

Acknowledgements

The author acknowledges the support and research facilities provided by College of Agriculture, Pune, Mahatma Phule Krishi Vidyapeeth, Rahuri, during the course of this research.

Conflict of interest

The authors declare no conflict of interest.

References

1. Dewey DR, Lu KH. A correlation and path-coefficient analysis of components of crested wheatgrass seed production. Agronomy Journal. 1959;51(9):515–518.
2. Wright S. Correlation and causation. Journal of Agricultural Research. 1921;20:557–585.
3. Diapari M, Sindhu A, Bett K, Deokar A, Shunmugam ASK, Tar'an B. Genetic diversity and association mapping of iron and zinc concentrations in chickpea (*Cicer arietinum* L.). Genome. 2014;57(8):459–468.
4. Upadhyaya HD, Bajaj D, Das S, Kumar V, Gowda CLL, Sharma S, Tyagi AK, Parida SK. Genetic dissection of seed-iron and zinc concentrations in chickpea. Scientific Reports. 2016;6:24050.
5. Samineni S, Mahendrakar MD, Shankar N, Hotti A, Chand U, Rathore A, Gaur PM. Impact of heat and drought stresses on grain nutrient content in chickpea: Genome-wide marker-trait associations for protein, Fe and Zn. Environmental and Experimental Botany. 2022;194:104688.
6. Johnson HW, Robinson HF, Comstock RE. Genotypic and phenotypic correlations in soybeans and their implications in selection. Agronomy Journal. 1955;47(10):477–483.
7. Chopdar DK, Bharti B, Sharma PP, Dubey RB, Brajendra, Meena BL. Studies on genetic variability, character association and path analysis for yield and its contributing traits in chickpea [*Cicer arietinum* (L.)]. Legume Research. 2017;40(5):824–829.
8. Umashankar, Kumar N, Reddy SPP, Bharadwaj C, Kumar T, Sharma PK, Chauhan SK. Identification of novel donors for yield contributing traits from Chickpea Adaptive Trials (CAT) of ICARDA for base broadening of Indian chickpea (*Cicer arietinum* L.). Electronic Journal of Plant Breeding. 2022;13(4):1395–1401.
9. Graham MH. Confronting multicollinearity in ecological multiple regression. Ecology. 2003;84(11):2809–2815.
10. Grewal SK, Sharma KP, Bhardwaj RD, Hegde V. Understanding genotypic variation and identification of promising genotypes for iron and zinc content in chickpea (*Cicer arietinum* L.). Journal of Food Composition and Analysis. 2020;88:103458.
11. Baidani A, Zeroual A, Abderemane BA, Mitache M, Aboutayeb R, Houasli C, Idrissi O. Genetic variability for protein, zinc, and iron content in a chickpea collection under no-tillage system conditions. Genetic Resources and Crop Evolution. 2025;72(3):3437–3448.

How to cite this article: Parveen N, Lad D, Bhagat A, Banoth S, Rajguru A. Character association and path coefficient analysis for seed yield, protein, iron and zinc in chickpea (*Cicer arietinum* L.). *International Journal of Agriculture and Food Science*. 2026;8(11):167-170. doi: https://www.doi.org/10.33545/2664844X.2026.v8.i11c.90089

2664844X, 2026, 8(11), Downloaded from https://www.doi.org/10.33545/2664844X.2026.v8.i11c.90089 by International Journal of Agriculture and Food Science on [04/11/2026]. See the Terms and Conditions (https://www.agriculturaljournals.com) for rules of use; OA articles are governed by the applicable Creative Commons License