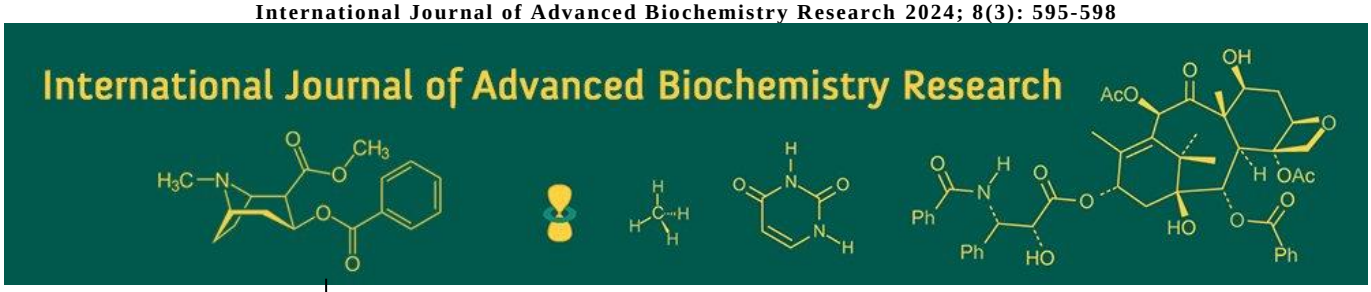

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Understanding correlation and path analysis in chickpea under late sown conditions

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Abstract
Chickpea (*Cicer arietinum* L.) is a vital legume crop worldwide, but its productivity is often compromised by late sowing conditions, leading to shorter crop durations and increased susceptibility to stresses. Understanding the interplay among agronomic traits and their association with yield under such conditions is crucial for chickpea improvement. This study investigates genotypic and phenotypic correlations and path analysis of key agronomic traits in chickpeas under late-sown conditions. Data were collected from field experiments comprising 37 chickpea genotypes including 4 checks grown under late sown conditions. Genotypic and phenotypic correlation analysis revealed associations on Seed yield per plant showed a highly significant and positive association with the biological yield per plant, harvest index, seeds per pod, 100 seed weight, pods per plant, and plant height. Path analysis elucidated direct and indirect pathways through which these traits influence yield on seed yield per plant were shown by biological yield followed by harvest index. This study provides valuable insights for chickpea breeding programs, facilitating the development of varieties better adapted to late sowing constraints. An improved understanding of trait interactions and their impact on yield resilience is crucial for enhancing chickpea productivity in the adverse growing environment.

Keywords: Path analysis, chickpea, *Cicer arietinum* L.

Introduction
Chickpea (*Cicer arietinum* L.) is one of the most important pulse crops globally, contributing significantly to human nutrition and agricultural economies (Begum *et al.*, 2017) [4]. However, its productivity is often challenged by various environmental stresses, including late sowing conditions, which adversely affect its growth and yield potential (Teng *et al.*, 2023) [19]. Late sowing leads to shorter crop duration, altered phenology, and increased susceptibility to biotic and abiotic stresses, posing a significant challenge to chickpea cultivation in many regions (Mehrotra *et al*., 2023) [11].

In the face of such challenges, understanding the interrelationships among various agronomic traits and their association with yield is crucial for chickpea improvement programs. Genotypic and phenotypic correlation analysis provides valuable insights into the degree and direction of association among different traits, aiding breeders in selecting appropriate breeding strategies (Manjunathagowda *et al.*, 2022) [9]. Moreover, path analysis offers a more comprehensive understanding of the direct and indirect effects of different traits on yield under specific environmental conditions (Yahaya *et al.*, 2021) [25].

This research paper aims to investigate the genotypic and phenotypic correlation among key agronomic traits and their contribution to yield in chickpea under late sown conditions. By employing path analysis, we seek to elucidate the direct and indirect pathways through which various traits influence yield performance, thus providing a holistic perspective on the complex interactions governing chickpea productivity in challenging growing environments.

The findings of this study hold significant implications for chickpea breeding and management practices under late sown conditions. We present the methodology employed for data collection and analysis, followed by the results of genotypic and phenotypic correlation analysis. Subsequently, we conduct a path analysis to unravel the complex relationships among different agronomic traits and their impact on chickpea yield under late sown conditions. Finally, we discuss the implications of our findings and highlight avenues

for future research aimed at further enhancing chickpea productivity and resilience in adverse growing environments.

Materials and Methods

The field experiment under present investigation was conducted in rabi season 2021-22 at the Genetics and Plant Breeding Farm, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.). Geographically Narendra Nagar is situated between 26.47 ^{o} N latitude, 82.12^{o} E longitude and at an altitude of 113 meters above the mean sea level. The climate of district Ayodhya is Semi-arid with hot summer and cold winter. Nearly 80% of total rainfall is received during the monsoon with a few showers in the winter. The soil type of experimental site was saline and inland alkaline with pH=9.1 and EC= 4.3dSm^{-1}. Experimental material exhibited a wide spectrum of variation for agronomical and morphological characters. The check used in the experiment is well adopted varieties of the region.

Results and Discussion

In the present investigation, Genotypic and phenotypic Correlation Coefficient with seed yield per plant and relationships among other traits were in Table 1 and 2 described below.

Genotypic Correlation Coefficient Analysis

By identifying traits with strong correlations and elucidating their causal relationships with yield, this research will contribute to the development of high-yielding chickpea varieties better suited to late-sowing conditions. Seed yield per plant showed a highly significant and positive association with the biological yield per plant (0.989**), harvest index (0.687**), seeds per pod, 100 seed weight, pods per plant, plant height, and non-significant positive association with the secondary branches per plant (0.135). Negative significant association with days to 50% flowering (-0.477*). (Ali *et al*., 2010, Cokkizgin *et al.*, 2013, Petrova and Desheva., 2016, Agrawal *et al.*, 2018, Gulwane *et al.*, 2022, Tare *et al*., 2023.) [2, 5, 17, 1, 6, 18]

Phenotypic correlation coefficient

Seed yield per plant showed a high positive and significant association with biological yield (0.918**), 100 seed weight (0.649**), harvest index(0.634**), seeds per pod (0.613**), number of pods per plant (0.588**), plant height (0.384**) and showed positive non-significant association with primary branches per plant (0.034) and secondary branches per plant (0.120), While high negative significant association with days to 50% flowering (-0.465**), and negative non-significant association with days to maturity (-0.144). (Jha *et al.*, 2012, Padmavathi *et al.*, 2013, Srivastava *et al.*, 2017, Mohan and Thiyagarajan. 2019, Ningwal *et al.*, 2023, Yadav *et al., 2023*.) [7, 15, 22, 12, 14, 24]

Path Coefficient Analysis

The path coefficient analysis was carried out by using simple correlation coefficients to assess the direct and indirect effects of ten independent characters on dependent character seed yield per plant have been presented in Tables 3 and 4.

Genotypic Path Matrix: High-order positive direct effects on seed yield per plant were shown by biological yield per plant (1.22) followed by harvest index (0.989). High-order positive indirect effects on seed yield per plant were shown by seeds per pod (0.867), 100-seed weight (0.773), pods per plant (0.755), and harvest index (0.720) via biological yield. Considerable negative direct effects on seed yield per plant were shown by 100 seed weight (-0.237), followed by seeds per pod (-0.193) and pods per plant (-0.171). The 100-seed weight showed the substantial negative indirect effect on seed yield per plant via biological yield (-0.149) and harvest index (-0.144). The remaining estimates of direct and indirect effects were too low to be considered in any direction. The estimates of residual effect were very low (0.0222).

Phenotypic Path Matrix: High-order positive direct effects on seed yield per plant were shown by biological yield (1.072) followed by harvest index (0.270). High-order positive indirect effects on seed yield per plant were shown by seeds per pod (0.669), 100-seed weight (0.659), and pods per plant (0.622) via biological yield. Considerable negative indirect effects on seed yield per plant were shown by biological yield via days to 50% flowering (-0.505), and days to maturity (-0.153). The remaining estimates of direct and indirect effects were too low to be considered in any direction. The estimates of residual factor (0.0629) were very low.

Path coefficient analysis is a technique for separating the observed correlation coefficient into direct and indirect effects of grain yield components. To formulate an efficient selection strategy, path analysis provides a clearer picture of character associations. (Kayan and Adak. 2012, Mushtaq *et al.*, 2013, Shafique *et al.*, 2016, Banik *et al.*, 2017, Sozen and Karadavut 2018, Meena *et al.*, 2021, Paul *et al.*, 2022, Ningwal *et al.*, 2023.) [8, 13, 20, 3, 21, 10, 16, 14]

Table 1: Estimates of genotypic correlation coefficients between eleven characters

Traits	Days to maturity	Primary branches/plant	Secondary branches/plant	Plant height (cm)	Pods/plant	Seeds/pod	100 Seed weight (g)	Biological yield/plant (g)	Harvest index (%)	Seed yield/plant (g)
Days to 50% flowering	0.618**	0.337**	0.185*	-0.459**	-0.344**	-0.520**	-0.181	-0.488**	-0.319**	-0.477**
Days to maturity		0.156	-0.202*	0.067	0.043	-0.206*	-0.089	-0.155	-0.030	-0.144
Primary branches/plant			0.215*	-0.248**	0.111	-0.393**	0.208*	0.029	0.001	0.048
Secondary branches/plant				-0.365**	-0.141	0.112	0.104	0.131	-0.034	0.135
Plant height (cm)					0.436**	0.466**	0.068	0.419**	0.230*	0.390**
Pods/plant						0.345**	0.081	0.615**	0.519**	0.632**
Seeds/Pod							0.100	0.706**	0.299**	0.668**
100 seed weight (g)								0.629**	0.607**	0.660**
Biological yield/plant (g)									0.586**	0.989**
Harvest index (%)										0.687**

*&** significant at 5% & 1% probability level respectively

Table 2: Estimates of phenotypic correlation coefficients between eleven characters

Traits	Days to maturity	Primary branches/plant	Secondary branches/plant	Plant height (cm)	Pods/plant	Seeds/pod	100 Seed weight (g)	Biological yield/plant (g)	Harvest index (%)	Seed yield/plant (g)
Days to 50% flowering	0.590**	0.267**	0.173	-0.437**	-0.321**	-0.443**	-0.176	-0.471**	-0.298**	-0.465**
Days to maturity		0.097	-0.158	0.066	0.048	-0.209*	-0.076	-0.143	-0.080	-0.144
Primary branches/plant			0.156	-0.176	0.122	-0.331**	0.164	0.010	0.028	0.034
Secondary branches/plant				-0.313**	-0.116	0.095	0.080	0.130	-0.077	0.120
Plant height(cm)					0.409**	0.409**	0.064	0.413**	0.202*	0.384**
Pods/plant						0.166	0.070	0.580**	0.402**	0.588**
Seeds/Pod							0.070	0.624**	0.324**	0.613**
100 seed weight (g)								0.614**	0.539**	0.649**
Biological yield / plant (g)									0.486**	0.981**
Harvest index (%)										0.634**

*&** significant at 5% & 1% probability level respectively

Table 3: Direct and indirect effects on ten characters on seed yield per plant (Genotypic)

Traits	Days to 50% flowering	Days to maturity	Primary branches/plant	Secondary branches/ plant	Plant height (cm)	Pods/plant	Seeds/pod	100 Seed weight (g)	Biological yield/plant (g)	Harvest index (%)	Seed yield/plant (g)
Days to 50% flowering	-0.003	0.002	0.001	0.001	0.001	0.059	0.100	0.043	-0.599	-0.082	-0.477**
Days to maturity	-0.002	0.003	0.000	-0.001	0.000	-0.007	0.040	0.021	-0.191	-0.008	-0.144
Primary branches/plant	-0.001	0.001	0.003	0.001	0.001	-0.019	0.076	-0.049	0.036	0.000	0.048
Secondary branches/plant	-0.001	-0.001	0.001	0.004	0.001	0.024	-0.022	-0.025	0.161	-0.009	0.135
Plant height (cm)	0.001	0.000	-0.001	-0.002	-0.003	-0.074	-0.090	-0.016	0.515	0.059	0.390**
Pods/plant	0.001	0.000	0.000	-0.001	-0.001	-0.171	-0.066	-0.019	0.755	0.133	0.632**
Seeds/pod	0.001	-0.001	-0.001	0.001	-0.001	-0.059	-0.193	-0.024	0.867	0.077	0.668**
100 seed weight (g)	0.001	0.000	0.001	0.001	0.000	-0.014	-0.019	-0.237	0.773	0.156	0.660**
Biological yield/plant (g)	0.001	-0.001	0.000	0.001	-0.001	-0.105	-0.136	-0.149	1.228	0.151	0.989**
Harvest index (%)	0.001	0.000	0.000	0.000	-0.001	-0.089	-0.058	-0.144	0.720	0.257	0.687**

RESIDUAL EFFECT = 0.0222, Direct effects on the main diagonal (bold figures)

Table 4: Direct and indirect effects of ten characters on seed yield per plant (Phenotypic)

Traits	Days to 50% flowering	Days to maturity	Primary branches/plant	Secondary branches/plant	Plant height (cm)	Pods/plant	Seeds /pod	100 Seed weight (g)	Biological yield/plant (g)	Harvest index (%)	Seed yield/ plant (g)
Days to 50% flowering	0.002	0.001	0.004	0.001	0.004	0.036	0.047	0.025	-0.505	-0.081	-0.465**
Days to maturity	0.001	0.002	0.001	-0.001	-0.001	-0.005	0.022	0.011	-0.153	-0.022	-0.144
Primary branches/plant	0.001	0.000	0.014	0.001	0.002	-0.014	0.035	-0.023	0.011	0.008	0.034
Secondary branches/plant	0.000	0.000	0.002	0.004	0.003	0.013	-0.010	-0.011	0.140	-0.021	0.120
Plant height (cm)	-0.001	0.000	-0.003	-0.001	-0.010	-0.046	-0.043	-0.009	0.442	0.055	0.384**
Pods/plant	-0.001	0.000	0.002	-0.001	-0.004	-0.112	-0.018	-0.010	0.622	0.109	0.588**
Seeds/pod	-0.001	0.000	-0.005	0.000	-0.004	-0.019	-0.106	-0.010	0.669	0.088	0.613**
100 seed weight (g)	0.000	0.000	0.002	0.000	-0.001	-0.008	-0.007	-0.141	0.659	0.146	0.649**
Biological yield/plant (g)	-0.001	0.000	0.000	0.001	-0.004	-0.065	-0.066	-0.087	1.072	0.132	0.981**
Harvest index (%)	-0.001	0.000	0.000	0.000	-0.002	-0.045	-0.034	-0.076	0.521	0.270	0.634**

R SQUARE =0.9960, RESIDUAL EFFECT =0.0629
Bold value shows direct and normal values shows indirect effects

Conclusion

The correlation coefficient showed positive and highly significant among biological yield per plant, 100 seed weight, seeds per pod, pods per plant with seed yield per plant; 100 seed weight with biological yield per plant; days to maturity, and primary branches per plant with days to 50 % flowering and plant height with seeds per pod; days to 50% flowering with days to maturity. The perusal of the table revealed that the highest positive and substantial direct effects on seed yield per plant were exerted by biological yield followed by harvest index. The negative and substantial direct effects on seed yield per plant were exerted by 100 seed weights, followed by pods per plant. The high indirect effects on seed yield per plant by seeds per pod, 100-seed weight, and pods per plant, harvest index via biological yield; and rest of the characters indirect contribution showed very low and negative effects on seed yield. Selecting superior crop genotypes requires genetic diversity. This research helped to the discovery of significant variables that directly or indirectly high yield of chickpea plants can possibly be obtained by selecting breeding materials with high plant height, biological yield per plant and pods per plant.

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