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Correlation and path coefficient analysis for seed yield and yield related traits in pigeon pea [*Cajanus cajan* (L.) Millsp.]

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Abstract
The study entitled Correlation and Path Coefficient Analysis for Seed Yield and Yield related traits in pigeon pea [*Cajanus cajan* (L.) Millsp.] took place at the Research and Education farm, Botany Department, College of Agriculture, Dapoli, during the Kharif season of 2022 across 14 various traits of Pigeon pea.
The present study "Correlation and Path Coefficient Analysis for Seed Yield and Yield related traits in pigeon pea" aimed to evaluate the association and contribution of various agronomic and yield-related traits toward seed yield per plant in Pigeon pea by employing genotypic and phenotypic correlation and path coefficient analysis. Significant variability was observed among genotypes for all traits studied. Correlation analysis revealed that traits such as number of pods per plant, test weight, harvest index, and seed yield per plot had a strong positive association with seed yield per plant at both genotypic and phenotypic levels.
Path coefficient analysis at the phenotypic level indicated that seed yield per plot, harvest index, and test weight had substantial positive direct effects on seed yield per plant, suggesting their critical role in yield determination. At the genotypic level, test weight, days to 50% flowering, seed yield per plot, and harvest index exhibited high positive direct effects, while pod length and plant height exerted notable negative direct effects.
The findings suggest that selecting genotypes with higher test weight, harvest index, and seed yield per plot can effectively enhance seed yield per plant. The integration of correlation and path analysis provides comprehensive insight for targeted selection in breeding programs.

Keywords: Correlation, path coefficient, genotypic, phenotypic

Introduction
Pigeon pea (*Cajanus cajan* L.) is a vital legume crop grown mainly in tropical and subtropical regions. It belongs to the family Fabaceae and is mainly grown for its edible seeds, which serve as a significant source of protein in many developing countries. The crop is believed to have originated in the Indian subcontinent, where it has been cultivated for over 3,000 years. From India, it spread to Africa and later to Central and South America. It serves as a significant source of protein for millions, especially in developing countries. It is an important leguminous crop widely cultivated in tropical and subtropical regions for its high protein seeds and adaptability to diverse agro-climatic conditions. Besides its nutritional value, pigeon pea contributes to soil fertility through nitrogen fixation, making it an integral part of sustainable cropping systems. Known for its drought tolerance and adaptability to marginal soils, pigeon pea is important in sustainable agriculture systems. Its ability to fix atmospheric nitrogen enhances soil fertility, making it an excellent choice for crop rotation and intercropping. Despite its importance, pigeon pea productivity remains low due to several biotic and abiotic constraints. Improving seed yield through breeding programs requires an understanding of the relationships among yield-contributing traits. Pigeon pea seeds are rich in proteins (20-25%), carbohydrates, dietary fiber, and essential amino acids like lysine. They also contain significant levels of iron, calcium, and vitamins such as thiamine and riboflavin. This nutritional profile makes pigeon pea a crucial part of the diet in vegetarian and protein- deficient regions.

Economically, pigeon pea is a vital cash crop for smallholder farmers. Its role in providing food security and income in semi-arid regions is significant. Ecologically, the crop improves soil health through nitrogen fixation, reduces erosion due to its canopy cover, and serves as forage for livestock in mixed farming systems. Pigeon pea stands out as a climate-resilient, nutritious, and economically valuable crop, particularly in regions facing food insecurity and environmental degradation. Continued research and policy support are essential to harness its full potential in sustainable agriculture and rural livelihoods. Correlation and path coefficient analyses are key statistical tools that help dissect complex traits like yield into component factors, facilitating the identification of traits with direct and indirect effects on yield.

Material and Methods

The present study was conducted during the Kharif season of 2022 at the Educational and Research Farm, Botany Department, College of Agriculture, Dapoli, Dist. Ratnagiri, Maharashtra. Meteorological data during the experiment period were recorded from the meteorological observatory located at the Department of Agronomy, College of Agriculture, Dapoli.

The experiment was laid out in a randomized block design (RBD) with two replications. Each experimental plot measured approximately 10.80 meters in length and 1.20 meters in width, comprising two rows per genotype. Each row consisted of 18 plants, making a total of 36 plants per plot. For detailed phenotypic and genotypic observations, five plants were randomly selected from each genotype within the plots.

A total of fourteen traits were recorded for each selected plant, including Days to Flower Initiation, Days to 50% Flowering, Days to Maturity, Number of Branches per Plant, Number of Seeds per Pod, Number of Pods per Plant, Percent Pod Borer Damage, Test Weight, Pod Length, Plant Height, Seed Yield per Plant, Seed Yield per Plot, Harvest Index, and Protein Content. These observations formed the basis for subsequent correlation and path coefficient analyses to assess the direct and indirect effects of these traits on seed yield.

Result and Discussion Correlation Analysis

Phenotypic correlation analysis (Table no 1) showed that seed yield per plant had significant positive associations with number of branches per plant, number of pods per plant, test weight, harvest index, and protein content. These traits are critical contributors to yield improvement. Negative phenotypic correlations were observed for days to flower initiation and percent pod borer damage, indicating that earlier flowering and lower pest damage favor higher seed yield. Tharageshwari and Hemavathy (2020) [25] for highly significant positive correlation of seed yield per plant on seed yield per plot. Same results were also observed by Jaggal *et al.* (2012) and Chisa *et al.* (2021) [3].

Genotypic correlations (Table no 2) were generally stronger than phenotypic correlations. Seed yield per plant exhibited high positive genotypic correlations with days to 50% flowering, number of branches per plant, test weight, harvest index, and seed yield per plot, suggesting these traits are genetically linked and can be targeted for selection in breeding programs. Conversely, pod length and days to flower initiation had significant negative genotypic correlations with seed yield, indicating that longer pods and later flowering might reduce yield potential under the given conditions. Rao and Rao (2020) [20] reported significant positive correlation for test weight and significant negative correlation for pod length.

Path Coefficient Analysis

At the phenotypic level, the path coefficient analysis (Table no 3) showed that seed yield per plot (0.6103) had the highest direct positive effect on seed yield per plant, followed by harvest index (0.1995) and test weight (0.1349). These traits also contributed substantial positive indirect effects via other traits. Conversely, traits such as percent pod borer damage (- 0.0841), days to flower initiation (-0.0924), and plant height (-0.0042) exerted negative direct effects. Tharageshwari and Hemavathy (2020) [25] reported the same results.

Traits like number of pods per plant (0.0954), number of seeds per pod (0.0402), and number of branches per plant (0.0176) had negligible direct effects, but contributed positively via indirect paths. The residual effect at the phenotypic level was 0.435, suggesting a reasonable model fit. The result was in confirmation with Pushpavalli *et al.* (2018) [18], it had indirect effect through number of pods per plant. At the genotypic level, (Table no 4) test weight (0.5058), days to 50% flowering (0.5321), seed yield per plot (0.5748), and harvest index (0.3473) exhibited high positive direct effects on seed yield per plant. In contrast, pod length (-0.5871), plant height (-0.1872), and number of seeds per pod (-0.2660) showed substantial negative direct effects. Kandarkar *et al.* (2020) [7] and Pal *et al.* (2018) [13], ended with similar results for positive direct effect on seed yield per plant. Saroj *et al.* (2013) [22] and Techale *et al.* (2013) [24] recorded similar findings for negative indirect effect on number of pods per plant. Traits such as number of branches per plant (0.3953) and percent pod borer damage (0.1811) also recorded moderate positive direct effects, with several supporting indirect contributions via other traits. The residual effect was 0.285, indicating that the majority of variation in seed yield per plant was accounted for by the studied traits.

Table 1: Estimates of phenotypic correlation coefficient between different characters in pigeon pea.

Characters	DFI	DFF	DTM	PH	NBPP	NSPP	NPPP	PPBD	TW	PC	HI	PL	SYPP	SYP.PL
DFI	1.0000	0.920**	0.496**	0.1252	-0.297*	-0.1909	-0.0251	-0.266*	0.448**	0.272*	0.0066	- 0.1264	0.1422	0.1165
DFF		1.0000	0.514**	0.1430	-0.237*	-0.1740	0.0077	-0.296*	0.455**	0.252*	0.0331	- 0.1050	0.1519	0.1479
DTM			1.0000	0.0725	-0.1422	-0.1136	0.0905	- 0.378**	0.1618	0.376**	0.261*	0.0084	0.418**	0.360**
PH				1.0000	0.440**	0.1967	0.288*	0.1538	0.0220	0.283*	0.1444	0.0668	0.1853	0.1677
NBPP					1.0000	0.390**	0.414**	0.1144	-0.259*	0.1567	0.2057	0.0263	0.227*	0.219*
NSPP						1.0000	0.236*	0.1440	-0.1227	0.0910	0.1127	0.1722	0.223*	0.2066
NPPP							1.0000	-0.1870	-0.0750	0.357*	0.557**	0.0970	0.595**	0.595**
PPBD								1.0000	-0.2095	-0.1061	- 0.386**	- 0.0855	- 0.380**	-0.430**
TW									1.0000	0.1329	-0.1298	- 0.1603	0.1846	0.2054
PC										1.0000	0.252*	- 0.0055	0.337*	0.315*
HI											1.0000	0.1642	0.688**	0.702**
PL												1.0000	0.1646	0.1486
SYPP													1.0000	0.876**
SYP.PL														1.0000

*Significant at 5% level, **Significant at 1% level

Table 2: Estimates of genotypic correlation coefficient between different characters in pigeon pea.

Characters	DFI	DFF	DTM	PH	NBPP	NSPP	NPPP	PPBD	TW	PC	HI	PL	SYPP	SYPPL
DFI	1.0000	0.992**	0.565**	0.264*	-0.294*	- 0.409**	-0.0010	-0.288*	0.523**	0.897**	-0.0100	0.407**	0.1864	0.2021
DFF		1.0000	0.575**	0.2072	-0.296*	- 0.363**	0.0350	-0.325*	0.511**	0.917**	0.0098	0.405**	0.1804	0.1967
DTM			1.0000	0.0390	-0.1982	-0.353*	0.1080	- 0.474**	0.2044	0.868**	0.262*	0.0446	0.465**	0.381**
PH				1.0000	0.527**	0.292*	0.319*	0.2007	0.0206	0.0981	0.1985	-0.0385	0.306*	0.329*
NBPP					1.0000	0.604**	0.564**	0.0865	- 0.378**	0.382**	0.237*	-0.251*	0.2101	0.2063
NSPP						1.0000	0.340*	0.337*	-0.1638	0.1383	0.1710	- 0.471**	0.360**	0.347*
NPPP							1.0000	-0.1780	-0.0733	0.824**	0.673**	-0.310*	0.769**	0.753**
PPBD								1.0000	-0.275*	- 0.513**	- 0.481**	0.0545	- 0.486**	- 0.559**
TW									1.0000	0.623**	-0.1317	0.424**	0.1695	0.2170
PC										1.0000	0.825**	0.465**	0.785**	0.888**
HI											1.0000	- 0.411**	0.759**	0.804**
PL												1.0000	- 0.463**	- 0.692**
SYPP													1.0000	0.902**
SYP.PL														1.0000

*Significant at 5% level, **Significant at 1% level

Note: DFI- Days to flower initiation, DFF- Days to 50% flowering, DTM- Days to maturity, NBPP- Number of branches per plant, NSPP- Number of seeds per plant, NPPP- Number of pods per plant, PPBD- Percent pod borer damage, TW- Test weight, PL- Pod length, PH- Plant height, SYPP- Seed yield per plot, SYP.PL- Seed yield per plant, HI- Harvest index, PC- Protein content

Table 3: Correlation Matrix Showing Inter-Relationships Among Different Morphological and Yield Characters

Characters	DFI	DFF	DTM	PH	NBPP	NSPP	NPPP	PPBD	TW	PC	HI	PL	SYPP	SYP.PL
DFI	-0.0924	-0.0850	-0.0458	-0.0116	0.0274	0.0176	0.0023	0.0246	-0.0414	-0.0251	-0.0006	0.0117	-0.0131	0.1165
DFF	0.0457	0.0496	0.0255	0.0071	-0.0118	-0.0086	0.0004	-0.0147	0.0226	0.0125	0.0016	-0.0052	0.0075	0.1479
DTM	0.0096	0.0099	0.0193	0.0014	-0.0028	-0.0022	0.0018	-0.0073	0.0031	0.0073	0.0051	0.0002	0.0081	0.360**
PH	-0.0005	-0.0006	-0.0003	-0.0042	-0.0018	-0.0008	-0.0012	-0.0006	-0.0001	-0.0012	-0.0006	-0.0003	-0.0008	0.1677
NBPP	-0.0052	-0.0042	-0.0025	0.0078	0.0176	0.0069	0.0073	0.0020	-0.0046	0.0028	0.0036	0.0005	0.0040	0.219*
NSPP	-0.0077	-0.0070	-0.0046	0.0079	0.0157	0.0402	0.0095	0.0058	-0.0049	0.0037	0.0045	0.0069	0.0090	0.2066
NPPP	-0.0024	0.0007	0.0086	0.0275	0.0395	0.0225	0.0954	-0.0178	-0.0072	0.0340	0.0531	0.0093	0.0568	0.595**
PPBD	0.0224	0.0249	0.0318	-0.0129	-0.0096	-0.0121	0.0157	-0.0841	0.0176	0.0089	0.0324	0.0072	0.0320	-0.430**
TW	0.0605	0.0614	0.0218	0.0030	-0.0350	-0.0166	-0.0101	-0.0283	0.1349	0.0179	-0.0175	-0.0216	0.0249	0.2054
PC	-0.0006	-0.0006	-0.0009	-0.0006	-0.0004	-0.0002	-0.0008	0.0002	-0.0003	-0.0023	-0.0006	0.0000	-0.0008	0.315*
HI	0.0013	0.0066	0.0521	0.0288	0.0410	0.0225	0.1110	-0.0769	-0.0259	0.0503	0.1995	0.0328	0.1372	0.702**
PL	-0.0009	-0.0007	0.0001	0.0005	0.0002	0.0012	0.0007	-0.0006	-0.0011	0.0000	0.0011	0.0069	0.0011	0.1486
SYPP	0.0868	0.0927	0.2550	0.1131	0.1388	0.1362	0.3633	-0.2319	0.1127	0.2057	0.4199	0.1004	0.6103	0.876**
SYP.PL	0.1165	0.1479	0.360**	0.1677	0.219*	0.2066	0.595**	-0.430**	0.2054	0.315*	0.702**	0.1486	0.876**	1.0000

Significant at 5% level, **Significant at 1% level

Note: DFI-Days to flower initiation, DFF- Days to 50% flowering, DTM- Days to maturity, NBPP- Number of branches per plant, NSPP- Number of seeds per plant, NPPP- Number of pods per plant, PPBD- Percent pod borer damage, TW- Test weight, PL- Pod length, PH- Plant height, SYPP- Seed yield per plot, SYP.PL- Seed yield per plant, HI- Harvest index, PC- Protein content.

Table 4: Correlation Matrix Showing Inter-Relationships Among Different Morphological and Yield Characters

Characters	DFI	DFF	DTM	PH	NBPP	NSPP	NPPP	PPBD	TW	PC	HI	PL	SYPP	SYP.PL
DFI	-0.1785	-0.1771	-0.1009	-0.0471	0.0524	0.0730	0.0002	0.0514	-0.0933	-0.1600	0.0018	-0.0726	-0.0333	0.2021
DFF	0.5279	0.5321	0.3059	0.1103	-0.1573	-0.1930	0.0186	-0.1727	0.2719	0.4878	0.0052	0.2152	0.0960	0.1967
DTM	-0.0350	-0.0356	-0.0619	-0.0024	0.0123	0.0219	-0.0067	0.0293	-0.0126	-0.0537	-0.0162	-0.0028	-0.0287	0.381**
PH	-0.0494	-0.0388	-0.0073	-0.1872	-0.0987	-0.0547	-0.0598	-0.0376	-0.0039	-0.0184	-0.0372	0.0072	-0.0572	0.329*
NBPP	-0.1161	-0.1169	-0.0783	0.2084	0.3953	0.2386	0.2230	0.0342	-0.1495	0.1510	0.0938	-0.0993	0.0830	0.2063
NSPP	0.1088	0.0965	0.0939	-0.0778	-0.1605	-0.2660	-0.0905	-0.0895	0.0436	0.0368	-0.0455	0.1252	-0.0956	0.347*
NPPP	-0.0001	0.0028	0.0085	0.0251	0.0444	0.0268	0.0787	-0.0140	-0.0058	0.1056	0.0530	-0.0244	0.0605	0.753**
PPBD	-0.0521	-0.0588	-0.0859	0.0363	0.0157	0.0609	-0.0322	0.1811	-0.0497	-0.0929	-0.0870	0.0099	-0.0880	-0.559**
TW	0.2644	0.2585	0.1034	0.0104	-0.1914	-0.0828	-0.0371	-0.1389	0.5058	0.3149	-0.0666	0.2145	0.0857	0.2170
PC	-0.1326	-0.1356	-0.1285	-0.0145	-0.0565	-0.0205	-0.1985	0.0759	-0.0921	-0.1479	-0.1221	-0.0688	-0.2313	0.888**
HI	-0.0035	0.0034	0.0911	0.0689	0.0824	0.0594	0.2338	-0.1669	-0.0457	0.2866	0.3473	-0.1427	0.2636	0.804**
PL	-0.2389	-0.2375	-0.0262	0.0226	0.1475	0.2764	0.1818	-0.0320	-0.2490	-0.2731	a0.2413	-0.5871	0.2720	-0.692**
SYPP	0.1071	0.1037	0.2670	0.1756	0.1207	0.2066	0.4418	-0.2794	0.0974	0.8987	0.4363	-0.2663	0.5748	0.902**
SYP.PL	0.2021	0.1967	0.381**	0.329*	0.2063	0.347*	0.753**	-0.559**	0.2170	0.888**	0.804**	-0.692**	0.902**	1.0000

Significant at 5% level, **Significant at 1% level

Note: DFI-Days to flower initiation, DFF- Days to 50% flowering, DTM- Days to maturity, NBPP- Number of branches per plant, NSPP- Number of seeds per plant, NPPP- Number of pods per plant, PPBD- Percent pod borer damage, TW- Test weight, PL- Pod length, PH- Plant height, SYPP- Seed yield per plot, SYP.PL- Seed yield per plant, HI- Harvest index, PC- Protein content

Conclusion

The study revealed that seed yield per plant in pigeon pea is a complex trait significantly influenced by multiple yield-contributing characters. Both phenotypic and genotypic correlation analyses identified number of pods per plant, harvest index, protein content, and seed yield per plot as the most

positively and significantly associated traits with seed yield per plant. Among negative associations, percent pod borer damage consistently showed a highly significant negative correlation at both levels.

Path coefficient analysis further established that seed yield per plot and harvest index exerted the highest positive direct effects on seed yield per plant at both phenotypic and genotypic levels, indicating their primary role as selection criteria in yield improvement. In contrast, pod length and percent pod borer damage exhibited high negative direct effects, suggesting their roles as constraints to productivity. Overall, the results emphasize that selection strategies in pigeon pea breeding should prioritize harvest index, number of pods per plant, protein content, and resistance to pod borer damage to achieve substantial gains in seed yield.

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