Original Research Article

Genetic Association and Path Coefficient Analysis in Black gram (*Vigna mungo* [L.] Hepper)

ABSTRACT

The present investigation was conducted at the Field Experimentation Centre, Department of Genetics and Plant Breeding, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh during the Zaid season of 2019. Fifty diverse genotypes of black gram were evaluated under field conditions to assess character association and contribution of yield-attributing traits through correlation and path coefficient analyses. The experimental site, located along the Prayagraj–Rewa National Highway, benefited from institutional support for resources and management, ensuring successful trial execution. Results revealed highly significant genotypic differences ($p \leq 0.05$) across all 12 studied traits, indicating substantial genetic variability with potential for crop improvement. Phenotypic and genotypic correlations demonstrated that seed yield per plant was significantly and positively associated with days to 50% flowering, plant height, number of pods per plant, pod length, 100-seed weight, biological yield, and harvest index, while number of branches per plant exhibited a significant negative association. Path analysis revealed that traits such as number of pods per plant, pod length, biological yield, and harvest index exerted the strongest positive direct effects on seed yield, while traits like number of seeds per pod and number of branches per plant showed negative direct effects. These results suggest that these yield-contributing traits play pivotal roles in black gram productivity. The findings reinforce the importance of targeting both direct and indirect contributors to yield in breeding strategies, supporting the development of high-yielding black gram cultivars for diverse agro-climatic conditions.

Keywords: *Vigna mungo*, Correlation analysis, Path analysis.

Introduction

According to the Indian Council of Medical Research (ICMR), the recommended per capita pulse consumption is 150 g/day, while the Food and Agriculture Organization (FAO) suggests 140 g/day. However, pulse productivity in India remains considerably lower than

that of other pulse-producing nations. Household consumption surveys reveal a decline in pulse consumption, contributing to increased malnutrition and reduced protein intake (Deekshith *et al.* 2022). With approximately 24% of the world's undernourished population residing in India (Sharma *et al.* 2016), pulses play a crucial role in ensuring food and nutritional security. Around 15.2% of India's population is undernourished, highlighting the importance of pulses in combating malnutrition. To bridge the domestic production gap, India imports roughly 2 million tonnes of pulses annually, costing approximately ₹3,000 crores. Black gram (*Vigna mungo* (L.) Hepper), commonly known as urdbean or mash, is a grain legume domesticated from *Vigna mungo* var. *silvestris*. It is a rich source of phosphoric acid and calcium, making it nutritionally valuable. Renowned for its fermenting properties, black gram is widely utilized in the preparation of fermented foods. It is cultivated both as a sole crop and as an intercrop, making it an essential component of various cropping systems. The low productivity of urd bean in both India and its states is attributed to multiple constraints, including the scarcity of quality seeds of high-yielding varieties, vulnerability to pre-harvest sprouting due to rainfall during the maturity stage, and the crop's sensitivity to intense precipitation, all of which significantly diminish yield potential. Consequently, this legume demands focused attention to enhance its production and productivity. Breeders have identified the lack of high-yielding and stable cultivars as a primary factor contributing to the poor productivity of pulses in general. Therefore, improving the genetic potential of black grams has become an imperative breeding objective. The evaluation of correlation coefficients provides a valuable opportunity to quantify both the strength and direction of relationships between yield and its contributing traits, as well as among various morphological and physiological attributes (Panigrahi and Baisakh, 2014). To further dissect these interrelationships, path coefficient analysis serves as a robust statistical tool, allowing for the partitioning of direct and indirect effects of different traits on grain yield (Pushpa *et al.* 2013). Given the significance of these analytical approaches, the present study was meticulously designed to assess genetic variability parameters, correlation coefficients, and path analysis under irrigated conditions in the Prayagraj region, thereby providing insights into trait associations and selection efficiency for yield enhancement. Assessing parental performance in contributing desirable genes to offspring is a fundamental prerequisite for systematic plant breeding aimed at developing superior varieties.

MATERIALS AND METHODS

At the Field Experimentation Centre of the Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, Uttar Pradesh a series of three experiments were conducted

during *Zaid-2019*. The prestigious university is conveniently accessible due to its strategic location along the Prayagraj–Rewa National Highway, about 5 kilometres from Prayagraj City. Through field preparation, the provision of necessary inputs, irrigation facilities, and labour resources, the Department of Horticulture provided unwavering support throughout the experimental period, ensuring the smooth and effective execution of this scientific endeavour. During *Zaid-2019*, (first year) 50 genotypes of black gram were evaluated under field conditions to identify the character association for yield contributing traits in black gram. The Fisher and Yates, 1963 method was used to statistically analyse the data. Correlation was calculated using methods suggested by Al-Jibouri *et al.* (1958) while path coefficient analysis was worked out my method suggested by Dewey and Lu (1959). The characters studied comprised of days to 50% flowering; days to 50% maturity; plant height (cm); number of branches per plant; number of clusters per plant; number of pods per plant; pod length (cm); number of seeds per pod; seed index (g); biological yield (g); seed yield per plant (g); harvest index (%).

RESULTS AND DISCUSSION

Analysis of Variance

Mean sum squares data for 12 characters of black gram studied in first season during *Zaid-2019*, were subjected to analysis of variance for experimental design. The analysis of variance for different characters calculated is presented in Table 1. The analysis of variance showed highly significant differences (α=0.05) among 50 genotypes for all characters studied indicating the presence of considerable amount of genetic variability among black gram germplasms. It also indicated the scope of selection for genetic improvement of black gram. This variability can be harnessed to improve yield and other agronomic traits through systematic breeding, making it possible to develop high-yielding and resilient black gram cultivars suited to different agro-climatic conditions. Hence, the findings justify further genetic studies and selection efforts for crop improvement. These findings are consistent with previous research by Khan *et al.* (2020), Patel and Bala (2020), Saran *et al.* (2021), Yergude *et al.* (2021) and Bharathi *et al.* (2022).

Correlation coefficient analysis

The results of the analysis of phenotypic correlation coefficients (table 2) showed that days to 50% flowering (0.315**), plant height (0.229*), number of pods per plant (0.511**), pod length (0.383**), 100-seed weight (0.325**), biological yield per plant (0.416**) and harvest index (0.257*) were all positively correlated with the seed yield per plant in black

gram. On the other hand, number of branches per plant (-0.252*)) showed negative significant correlation with seed yield per plant of black gram. Characters like days to 50% maturity (0.1109), number of clusters per plant (0.0985) and number of seeds per pod (0.092) did not exhibit a significant correlation with the seed yield per plant at phenotypic level. The potential productivity of a crop is primarily dictated by its seed yield per unit area, which is a complex, polygenic trait influenced by multiple contributing factors, including various agronomic characteristics and environmental conditions. Due to this complexity, direct selection for seed yield can be challenging. Therefore, it becomes crucial to assess the relationships between seed yield and its associated traits, as well as the interactions among these traits. By selecting for traits that are positively correlated with yield, the efficiency of selection can be improved. In the context of quantitative traits, the phenotypic expression and the strength and direction of associations between characters are shaped by both genetic and environmental factors, making it essential to understand these relationships for more effective breeding strategies (Sohel *et al.* 2016). The genotypic correlation coefficient analysis (table 2) revealed that several agronomic traits exhibited a significant positive association with seed yield per plant in black gram. Notably, days to 50% flowering (0.495**), plant height (0.295**), number of pods per plant (0.665**), pod length (0.529*), 100-seed weight (0.517**), biological yield per plant (0.527**), and harvest index (0.341*) demonstrated statistically significant and favourable correlations with seed productivity. Conversely, the number of branches per plant (-0.302*) exhibited a significant negative correlation with seed yield, indicating a potentially antagonistic relationship. Meanwhile, traits such as days to 50% maturity (0.1235), number of clusters per plant (0.1256), and number of seeds per pod (0.1453) were found to have non-significant genotypic associations with seed yield per plant, suggesting a limited direct influence on yield potential. Genotypic correlation reveals the extent to which two traits are controlled by the same genes or share a similar physiological basis. A positive genotypic correlation suggests that improving one trait would likely enhance others as well. This underscores the importance of understanding the relationship between seed yield and its contributing traits, as selecting for one factor could unintentionally improve others, facilitating a more efficient selection process. The analysis revealed that seed yield per plant had highly significant and positive correlations with traits such as days to 50% flowering, plant height, number of pods per plant, pod length, 100-seed weight, biological yield per plant and harvest index at phenotypic and genotypic level. Number of branches per plant depicting negative significant correlation with seed yield at both phenotypic and genotypic level. These correlations suggest that these traits are key determinants of seed yield in black gram. Interestingly, seed yield did not show a significant

correlation with number of seeds per pod, number of clusters per plant and days to 50% maturity further emphasizing the importance of focusing on specific traits for yield improvement. These findings align with previous research by Sagar *et al.* (2021), and Mishra and Lavanya (2021), who reported significant positive correlations between seed yield per plant and traits such as plant height, number of pods per plant, pod length, 100-seed weight, biological yield per plant. Similarly, studies by Aman and Singh (2022), Saran *et al.* (2022), and Vikas *et al.* (2023) concluded that seed yield was significantly positively correlated with days to 50% flowering and harvest index. The significant correlation between seed yield and harvest index was also noted by Yadav *et al.* (2023) and Ritika *et al.* (2024) along with negative association with number of branches per plant reinforcing the importance of these traits in breeding programs aimed at improving seed yield.

Path analysis

Phenotypic path coefficient analysis is the process of determining path coefficients based on the phenotypic correlation coefficient. Two measures of direct and indirect effects are obtained by splitting the phenotypic correlation coefficient (Table 3 & Figure 1). During *Zaid-2019*, the number of pods per plant (0.409), pod length (0.2707), harvest index (0.1952), biological yield per plant (0.1593), days to 50% flowering (0.0944), 100-seed weight (0.0519), days to 50% maturity (0.0314) and plant height (0.0026) showed the maximum positive direct effects on seed yield at the phenotypic level, while the number of branches per plant (-0.0655), number of clusters per plant (-0.1251) and number of seeds per pod (-0.129) showed the maximum negative direct effects. At the phenotypic level, the characters contributing the most to seed yield through their direct effects were number of pods per plant, pod length, harvest index, biological yield per plant, days to 50% flowering, 100-seed weight, days to 50% maturity and plant height with positive direct effects on seed yield at the phenotypic level, while the number of branches per plant, number of clusters per plant and number of seeds per pod showed the maximum negative direct effects.. These characters collectively accounted for 67.30% of the variability in seed yield, indicating that these 12 traits are key determinants in improving seed yield in black gram. Similar findings have been documented by previous researchers. Sagar *et al.* (2021) and Saran *et al.* (2022) reported that harvest index exhibited the highest positive direct effect on seed yield per plant. Senthilkumar *et al.* (2018) also highlighted the positive direct effect of the number of pods per plant and pod length on seed yield. Additionally, traits such as biological yield per plant, days to 50% flowering and 100-seed weight were found to have a positive direct effect on

seed yield, a conclusion supported by Sohel *et al.* (2016), Suryawanshi *et al.* (2018). While Yadav *et al.* (2023) and Ritika *et al.* (2024) reported similar findings for days to 50% maturity and plant height. Therefore, selecting based on these traits would lead to significant improvements in seed yield in black gram.

At the genotypic level (table 4 and figure 2), harvest index, number of pods per plant, days to 50% flowering, pod length, biological yield per plant and number of branches per plant exerted the most pronounced positive direct effects on seed yield, underscoring their crucial roles in enhancing the yield potential of black gram. These traits, by virtue of their strong direct contributions, represent valuable targets for selection in yield improvement programmes. Sohel *et al.* (2016) and Shanthi *et al.* (2019) reported similar findings in black gram. Conversely, plant height, days to 50% maturity, 100-seed weight, number of clusters per plant and number of seeds per pod revealed notable negative direct effects on seed yield, implying that these traits may negatively influence yield performance when their effects are considered in isolation through direct causal pathways. Hence, cautious consideration is required when incorporating these traits into selection criteria, as their enhancement may not directly translate into yield gains. Findings of negative direct effect was found to be in accordance with conclusions of Sagar *et al.* (2021) and Aman and Singh (2022). Path coefficient analysis further revealed that the high positive correlation of several traits with seed yield per plant was not solely due to their direct contributions but was also significantly influenced by their substantial indirect effects channelled through key yield-contributing traits. Characters such as harvest index, days to 50% flowering, plant height, number of primary branches per plant, pod length, number of pods per plant, seed index, and biological yield exerted strong indirect influences, thereby reinforcing their importance in the overall yield architecture of black gram. This highlights the complex interplay among traits and underscores that selection targeting these pivotal characters—whether for their direct or indirect influence—can effectively contribute to the enhancement of seed yield in breeding programs.

CONCLUSION

The present study highlights the intricate relationship between seed yield and its contributing traits in black gram. Both phenotypic and genotypic correlation analyses revealed significant and positive associations of seed yield per plant with traits such as days to 50% flowering, plant height, number of pods per plant, pod length, 100-seed weight, biological yield per plant, and harvest index, identifying them as key yield determinants. Conversely, number of

branches per plant consistently exhibited a negative correlation with seed yield, suggesting an antagonistic effect. Path coefficient analysis further supported these findings, showing that several traits influence seed yield not only directly but also through strong indirect effects. Traits like number of pods per plant, pod length, and harvest index had prominent direct contributions, while others like plant height and biological yield contributed indirectly. These results underscore the importance of a trait-based selection approach, enabling breeders to enhance seed yield by targeting traits with strong direct and indirect influence.

Table 1 Analysis of Variance (ANOVA) for 12 characters in 50 genotypes of black gram.

	ANOVA Summary			
Sl. No.	**Source**	**Mean Sum of Squares (MSS)**		
		Replications	**Genotypes**	**Error**
	Degrees of freedom	*n=2*	*n=49*	*n=98*
1	Days to 50% flowering	1.56	18.60**	3.74
2	Days to 50% maturity	8.91	14.67**	5.12
3	Plant height (cm)	39.17	311.84*	13.55
4	Number of branches per plant	0.01	13.06**	0.92
5	Number of clusters per plant	0.27	11.66**	1.13
6	Number of pods per plant	6.43	208.89*	10.38
7	Pod length (cm)	0.02	0.78**	0.11
8	Number of seeds per pod	0.34	1.47**	0.18
9	100 seed weight (g)	0.03	0.80**	0.08
10	Biological yield per plant	2.16	72.74*	4.78
11	Seed yield per plant (g)	0.87	8.44**	1.01
12	Harvest Index (%)	8.90	59.89**	7.86
**,* Significant at 1% and 5% level of significance respectively				

Table 2. Estimates of Correlation coefficients among grain yield characters of black gram genotypes

Characters	DF50	DM50	PH	NBP	NCPP	NPPP	PL	NSPP	SI	BYPP	HI	SYPP
Phenotypic correlation (below diagonal) and Genotypic Correlation (above diagonal) Matrix												
DF50	**1.000**	0.284**	0.283**	-0.318**	-0.048	0.162*	0.180*	0.227*	0.289**	0.226*	0.245*	0.315**
DM50	0.549**	**1.000**	0.206*	-0.136	-0.063	0.01	0.013	0.097	0.0174	0.1168	0.1066	0.1109
PH	0.406**	0.416**	**1.000**	-0.336**	-0.0467	0.061	0.114	0.141	0.231*	0.283**	0.364**	0.229*
NBP	-0.494**	-0.202*	-0.410**	**1.000**	0.1602	-0.109	0.032	-0.372**	-0.271**	-0.341**	-0.383**	-0.252*
NCPP	-0.125	-0.182*	-0.0664	0.192*	**1.000**	0.261*	0.389**	-0.248*	0.193*	0.0453	-0.105	0.0985
NPPP	0.191*	-0.0842	0.0634	-0.166*	0.325**	**1.000**	0.247*	0.210*	0.207*	0.280**	0.0863	0.511**
PL	0.307**	0.0351	0.1356	0.0337	0.500**	0.374**	**1.000**	-0.169*	0.228*	0.214*	-0.1193	0.383**
NSPP	0.316**	0.204*	0.187*	-0.512**	-0.305**	0.291**	-0.243*	**1.000**	0.190*	0.028	0.442**	0.092
SI	0.443**	0.0159	0.279**	-0.353**	0.214*	0.276**	0.365**	0.313**	**1.000**	0.257*	0.450**	0.325**
BYPP	0.306**	0.244*	0.315**	-0.427**	0.0623	0.330**	0.272**	0.0395	0.349**	**1.000**	0.166*	0.416**
HI	0.295**	0.238*	0.476**	-0.512**	-0.180*	0.1364	-0.1583	0.602**	0.610**	0.176*	**1.000**	0.257*
SYPP	0.495**	0.1235	0.295**	-0.302**	0.1256	0.665**	0.529*	0.1453	0.517**	0.527**	0.341*	**1.000**

(**Abbreviations: - DF50:-**Days to 50% flowering, **DM50:-**Days to 50% maturity, **PH:-**Plant height (cm), **NBP:-**Number of primary branches per plant, **NCPP:-**Number of clusters per plant, **NPPP:-**Number of pods per plant, **NSPP:-**Number of seeds per pod, **PL:-**Pod length (cm), **SI:-**100-seed weight (g), **BYPP:-**Biological Yield per plant (g), **HI:-**Harvest index (%), **SYPP:-**Seed yield per plant (g).

*,** **at 5% and 1% Level of Significance**

Table 3 Direct and Indirect effects of yield attributing traits on seed yield at phenotypic level

						Phenotypic Path Matrix						
Characters	DF50	DM50	PH	NBP	NCPP	NPPP	PL	NSPP	SI	BYPP	HI	SYPP
DF50	**0.0944**	0.0268	0.0268	-0.03	-0.0046	0.0153	0.017	0.0214	0.0273	0.0213	0.0231	0.315**
DM50	0.0089	**0.0314**	0.0065	-0.0043	-0.002	0.0003	0.0004	0.0031	0.0005	0.0037	0.0033	0.1109
PH	0.0007	0.0005	**0.0026**	-0.0009	-0.0001	0.0002	0.0003	0.0004	0.0006	0.0007	0.001	0.229*
NBP	0.0208	0.0089	0.022	**-0.0655**	-0.0105	0.0071	-0.0021	0.0243	0.0177	0.0223	0.0251	-0.252*
NCPP	0.006	0.0079	0.0058	-0.02	**-0.1251**	-0.0326	-0.0486	0.0311	-0.0242	-0.0057	0.0131	0.0985
NPPP	0.0661	0.004	0.0248	-0.0445	0.1066	**0.409**	0.1009	0.086	0.0846	0.1145	0.0353	0.511**
PL	0.0487	0.0035	0.031	0.0086	0.1053	0.0668	**0.2707**	-0.0456	0.0617	0.0579	-0.0323	0.383**
NSPP	-0.0292	-0.0126	-0.0182	0.0479	0.032	-0.0271	0.0217	**-0.129**	-0.0245	-0.0035	-0.057	0.092
SI	0.015	0.0009	0.012	-0.0141	0.01	0.0107	0.0118	0.0099	**0.0519**	0.0133	0.0234	0.325**
BYPP	0.0359	0.0186	0.0451	-0.0543	0.0072	0.0446	0.034	0.0044	0.041	**0.1593**	0.0264	0.416**
HI	0.0478	0.0208	0.071	-0.0747	-0.0205	0.0168	-0.0233	0.0862	0.0879	0.0323	**0.1952**	0.257*

Residual: 0.327

(**Abbreviations: - DF50:-**Days to 50% flowering, **DM50:-**Days to 50% maturity, **PH:-**Plant height (cm), **NBP:-**Number of primary branches per plant, **NCPP:-**Number of clusters per plant, **NPPP:-**Number of pods per plant, **NSPP:-**Number of seeds per pod, **PL:-**Pod length (cm), **SI:-**100-seed weight (g), **BYPP:-**Biological Yield per plant (g), **HI:-**Harvest index (%), **SYPP:-**Seed yield per plant (g).

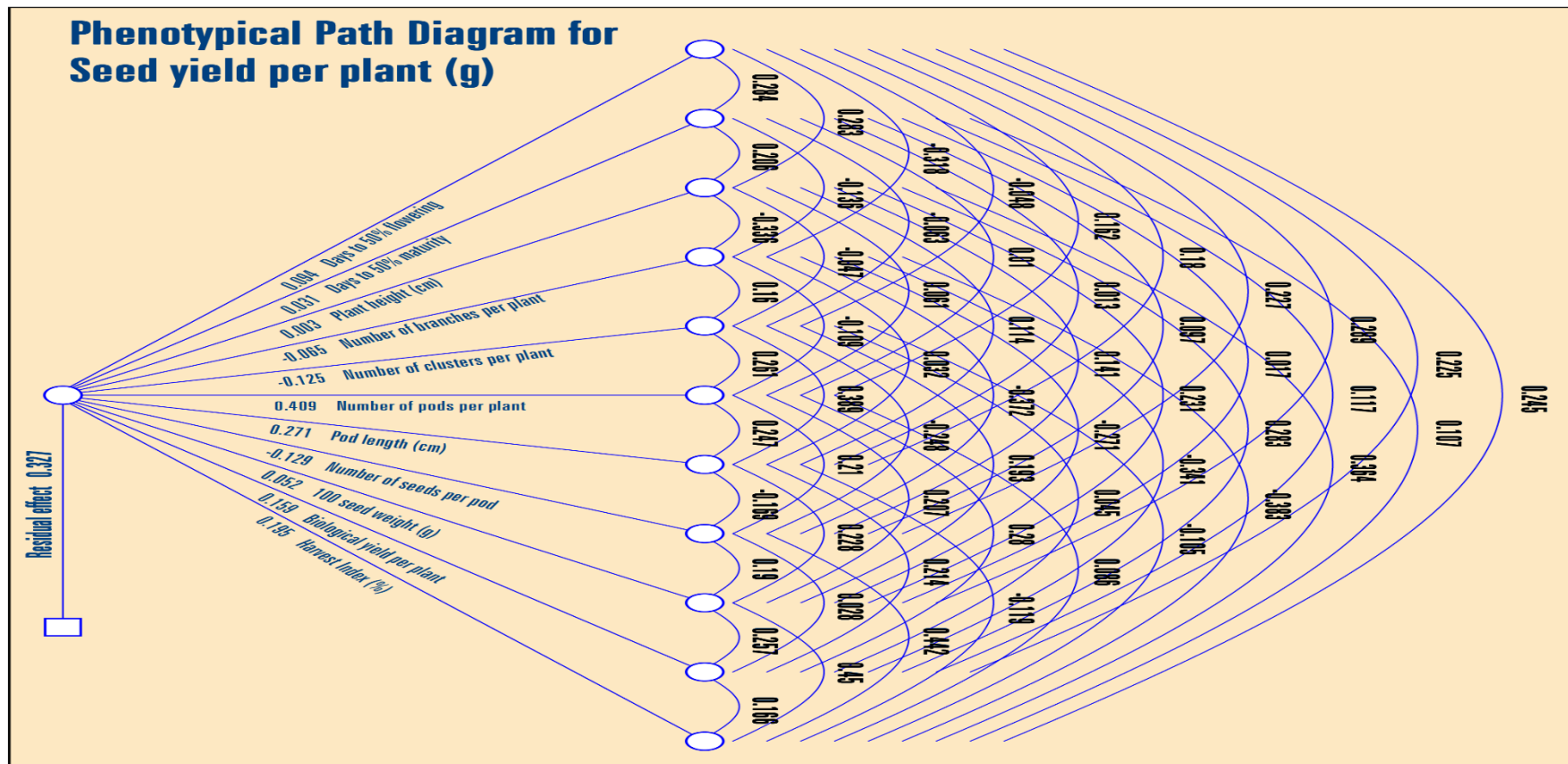*,** at 5% and 1% Level of Significance

Figure 1 Phenotypic path diagram for seed yield per plant

Table 4 Direct and Indirect effects of yield attributing traits on seed yield at genotypic level

Characters	DF50	DM50	PH	NBP	NCPP	NPPP	PL	NSPP	SI	BYPP	HI	SYPP
Genotypic Path Matrix												
DF50	**0.3617**	0.1985	0.1467	-0.1787	-0.0452	0.0692	0.1111	0.1143	0.1603	0.1105	0.1068	0.495**
DM50	-0.0853	**-0.1554**	-0.0647	0.0315	0.0283	0.0131	-0.0055	-0.0317	-0.0025	-0.0379	-0.0369	0.1235
PH	-0.0392	-0.0403	**-0.0967**	0.0396	0.0064	-0.0061	-0.0131	-0.0181	-0.027	-0.0305	-0.046	0.295**
NBP	-0.0588	-0.0241	-0.0488	**0.1191**	0.0229	-0.0197	0.004	-0.061	-0.0421	-0.0508	-0.061	-0.302**
NCPP	0.0242	0.0353	0.0129	-0.0373	**-0.1937**	-0.063	-0.0968	0.0592	-0.0415	-0.0121	0.0348	0.1256
NPPP	0.0974	-0.0429	0.0323	-0.0844	0.1657	**0.5095**	0.1907	0.1483	0.1408	0.1679	0.0695	0.665**
PL	0.1087	0.0124	0.048	0.0119	0.1769	0.1325	**0.3539**	-0.086	0.1293	0.0963	-0.056	0.529*
NSPP	-0.0967	-0.0624	-0.0573	0.1568	0.0935	-0.0891	0.0744	**-0.3062**	-0.0957	-0.0121	-0.1844	0.1453
SI	-0.0721	-0.0026	-0.0454	0.0575	-0.0348	-0.045	-0.0595	-0.0509	**-0.1628**	-0.0568	-0.0993	0.517**
BYPP	0.075	0.0598	0.0773	-0.1047	0.0153	0.0808	0.0667	0.0097	0.0857	**0.2453**	0.0432	0.527**
HI	0.1803	0.1452	0.2904	-0.3128	-0.1096	0.0833	-0.0967	0.3677	0.3725	0.1074	**0.6105**	0.341*

Residual: 0.211

(**Abbreviations: - DF50:-**Days to 50% flowering, **DM50:-**Days to 50% maturity, **PH:-**Plant height (cm), **NBP:-**Number of primary branches per plant, **NCPP:-**Number of clusters per plant, **NPPP:-**Number of pods per plant, **NSPP:-**Number of seeds per pod, **PL:-**Pod length (cm), **SI:-**100-seed weight (g), **BYPP:-**Biological Yield per plant (g), **HI:-**Harvest index (%), **SYPP:-**Seed yield per plant (g).
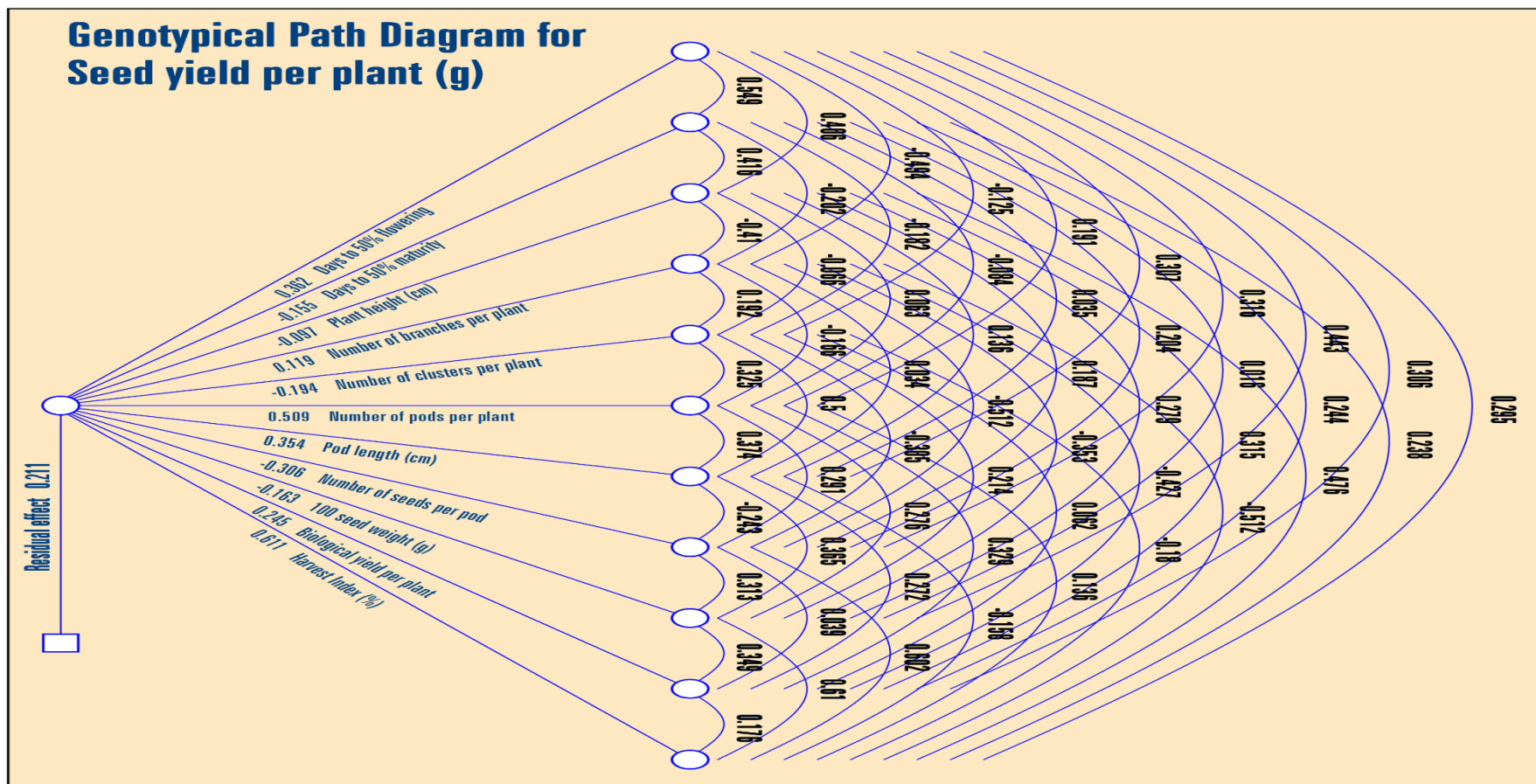
*,** at 5% and 1% Level of Significance**

Figure 2 Genotypic path diagram for seed yield per plant

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