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CORRELATION, PATH COEFFICIENT AND DISCRIMINANT FUNCTION ANALYSIS IN F_3 SEGREGANTS OF YARDLONG BEAN (*VIGNA UNGUICULATA* SSP. *SESQUIPEDALIS* L. VERDCOURT)

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ABSTRACT

Yard long bean [*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt] is a widely adapted, stress-tolerant legume vegetable crop, grown extensively in tropical and subtropical regions. An investigation was conducted on five F_3 families of yardlong bean and their populations to examine the relationships between yield components and to analyze both their direct and indirect effects on seed yield. Since yield is a complex trait influenced by multiple factors, understanding the relationships between these component traits is crucial for improving yield in breeding programs. A significant positive correlation between yield per plant and traits like pod weight, number of pods per plant, pod length, pod width, and harvest index. Pod weight and harvest index had the strongest direct effects on yield per plant, along with days to 50% flowering and pod width. Among five families, the F_3-1 family has the highest value of the selection index, followed by F_3-3 and F_3-3. Therefore, selecting F_3-1, F_3-3 and F_3-2 families with these traits will enhance yield in yard long bean in future breeding programmes.

Key words : Correlation, F_3 segregants, Path analysis, Selection index, Yard long bean, Yield.

Introduction

Yard long bean (*Vigna unguiculata* subsp. *sesquipedalis*, 2n=2x=22), also known as asparagus bean or Chinese long bean, is a versatile legume crop. This crop is widely grown in tropical and subtropical areas worldwide, valued for its long, tender pods that are used in various dishes. Rich in protein, dietary fiber, vitamins A and C, and essential minerals (Bhandari, 2015). In India, yard long bean cultivation spans approximately 29 million hectares, primarily in Kerala, Karnataka and Maharashtra (Rawat and Vima, 2023). Additionally, yard long bean contribute to soil health through their deep root systems, nitrogen fixation, improve water retention and prevent erosion (Suma *et al.*, 2021).

Yield is a complex trait influenced by multiple genes, making its inheritance polygenic. Unfortunately, the genetic gains from selecting for higher yields have been relatively low, largely because genotype-environment interactions and various component traits have a significant impact. Evaluating different segregants of yard long bean can provide valuable insights into this complexity (Sultana, 2017). By conducting correlation and path analysis among the genotypes, researchers can identify diverse parent lines to use in breeding programs aimed at creating high-yield varieties. These correlation studies allow plant breeders to select superior genotypes with traits linked to yield, as improving one trait can positively influence others. This study aims to investigate the relationships among different traits in yardlong bean segregants, specifically focusing on those that affect yield per plant.

Materials and Methods

Plant material

The study was conducted at the Department of

Genetics and Plant Breeding, College of Agriculture, Vellayani, Kerala Agricultural University during 2024. From the cross Kattampally local (Drought tolerant) × Vellayani Jyothika (High yielding) five F_3 families of yard long bean segregants were used in the investigation of Reddy *et al.* (2024) formed the material of this study.

Experimental design

The experiment followed a compact family block design, with five replications for each family, and five progenies per replication.

Statistical analysis

Characters like days to 50 % flowering, pod length, pod width, pod weight, pods per plant, vine length, harvest index, crop duration, and yield per plant were computed. The observed characters were subjected to various statistical analysis like correlation analysis, path coefficient analysis and discriminant function analysis. The correlation analysis between all observed traits, with yield as the dependent variable was carried out using the method proposed by Johnson *et al.* (1955). Path analysis, which helps identify the direct and indirect effects of traits on the dependent variable, was conducted following the approach outlined by Wright (1921) and Dewey and Lu (1959). The discriminant function analysis is a statistical method used to distinguish desirable genotypes from undesirable ones based on a combination of traits, was carried out using the method proposed by Smith (1936). The analysis was done using the GRAPES (General R-based Analysis Platform Empowered by Statistics (www.kaugrapes.com) software, V:1.10 (Gopinath *et al.*, 2020).

Results

Correlation analysis

Yield is a complex trait, making direct selection for yield less effective. Therefore, it's more important to focus on traits that are closely related to yield. Table 1 shows the genotypic and phenotypic correlations among fifteen traits in horse gram. In this study, the genotypic correlation coefficients for different traits with yield were generally higher than the phenotypic ones. This suggests a strong genetic link between the traits, with minimal influence from environmental factors.

The association studies showed a strong positive correlation between yield per plant and pod weight (r_g = 0.962, r_p = 0.906), with the number of pods per plant (r_g = 0.922, r_p = 0.842), pod length (r_g = 0.809, r_p = 0.746) and harvest index (r_g = 0.691, r_p =0.618) also contributing positively. On the other hand, there was a significant negative correlation with crop duration (r_g = -0.989, r_p =-0.774), followed by vine length (r_g = -0.871, r_p = -0.810) and days to 50% flowering (r_g = -0.626, r_p =0.618) at both genotypic and phenotypic level. For pod width at the genotypic level (rg =0.753), there is a significant positive correlation, but at the phenotypic level (rp =0.420), there is a positive but non-significant correlation with yield per plant.

Days to 50% flowering exhibited a significant positive correlation with vine length (r_g = 0.928, r_p =0.708), followed by crop duration (r_g = 0.849, r_p =0.505) and a significant negative correlation exhibited by pod length (r_g = -0.954, r_p = -0.696), pod weight (r_g = -0.674, r_p = -0.479), harvest index (r_g = -0.563, r_p = -0.653) and pods per plant (r_g = -0.544, r_p = -0.359) at both genotypic and phenotypic levels. Pod width showed a positive correlation, but it is non-significant, with days to 50 % flowering at both genotypic and phenotypic levels.

Pod length showed a significant positive correlation with pod weight (r_g = 0.758, r_p =0.626), followed by harvest index (r_g = 0.717, r_p = 0.790), and a significant negative correlation with crop duration (r_g = -0.997, r_p =-0.760), days to 50 % flowering (r_g = -0.954, r_p =-0.690), vine length (r_g = -0.907, r_p =-0.823), pod width showed positive correlation, but it is non-significant with pod length at both genotypic and phenotypic levels. At the genotypic level, pod per plant (r_g = 0.586) showed a significant positive correlation with pod weight, but at the phenotypic level (r_p = 0.417) showed a positive correlation but was non-significant with pod length.

Association studies exhibited a significant positive correlation between pod width with pods per plant (r_g = 0.924, r_p =0.591), followed by pod weight (r_g = 0.856, r_p =0.558) at both genotypic and phenotypic levels. A significant negative correlation was exhibited by vine length (r_g = -0.566) at the genotypic level, but at the phenotypic level (rp = -0.275), it was significant with pod width. The pod length, harvest index, and days to 50 % flowering showed a positive correlation, but crop duration showed a negative correlation, but it is non-significant with pod width at both genotypic and phenotypic levels.

Pod weight exhibited a significant positive correlation with pods per plant (r_g = 0.995, r_p = 0.870), pod width (r_g = 0.856, r_p = 0.558), pod length (r_g = 0.758, r_p = 0.626 and a significant negative correlation with crop duration (r_g = -0.951, r_p = -0.721), and vine length (r_g = -0.949, r_p = -0.810) at both genotypic and phenotypic levels. Harvest index (r_g = 0.525) showed a significant positive correlation with pods per plant at the genotypic level, but at the phenotypic level (r_p = 0.418) positive correlation, but it was non-significant with pod weight. Days to 50 %

Table 1 : Genotypic (below diagonal) and phenotypic correlation(above diagonal) of yield and other related characters of F_3 families of yard long bean.

	Days to 50% flowering	Pod length	Pod width	Pod weight	Pods per plant	Vine length	Harvest index	Crop duration	Yield per plant
Days to 50% flowering	1	-0.696*	0.056	-0.479	-0.359	0.708*	-0.653*	0.505*	-0.500*
Pod length	-0.954**	1	0.038	0.626*	0.497	-0.823**	0.790**	-0.760**	0.746*
Pod width	0.003	0.193	1	0.558*	0.591*	-0.275	-0.079	-0.483	0.426
Pod weight	-0.674*	0.758**	0.856**	1	0.87**	-0.81**	0.418	-0.721*	0.906**
Pods per plant	-0.544*	0.586*	0.924**	0.995**	1	-0.719*	0.447	-0.702*	0.842**
Vine length	0.928**	-0.907**	-0.566*	-0.949**	-0.845**	1	-0.545*	0.770**	-0.810**
Harvest index	-0.563*	0.717*	0.046	0.525*	0.438	-0.550*	1	-0.562*	0.618*
Crop duration	0.849**	-0.997**	-0.467	-0.951**	-0.791**	0.981**	-0.717*	1	-0.774**
Yield per plant	-0.626*	0.809**	0.753*	0.962**	0.922**	-0.871**	0.691*	-0.989**	1

*Significant at @ 5% ** significant at @1%

flowering (r_g = -0.674) exhibited a significant negative correlation with pod weight at the genotypic level, but at the phenotypic level (r_p = -0.479) showed a negative non-significant correlation with pod weight.

At both genotypic and phenotypic levels, the number of pods per plant showed a significant positive correlation with pod weight (r_g = 0.995, r_p = 0.870), pod width (r_g = 0.924, r_p = 0.591) and a negative correlation with vine length (r_g = -0.845, r_p = -0.919), crop duration (r_g = -0.791, r_p = -0.702). Both pod length (r_g = 0.586, r_p = 0.497) and days to 50% flowering (rg = -0.544, rp = -0.359) at the genotypic level is significant but at the phenotypic level, non-significant correlation with the number of pods per plant. The harvest index has a positive correlation, but it is non-significant with the number of pods per plant at both genotypic and phenotypic levels.

Vine length exhibited a significant positive correlation with days to 50% flowering (r_g = 0.928, r_p = 0.708) and crop duration (r_g = 0.981, r_p = 0.770) and a significant negative correlation with pod weight (r_g = -0.949, r_p = -0.810), pod length (r_g = -0.907, r_p = -0.823), pods per plant (r_g = -0.845, r_p = -0.719), and harvest index (r_g = -0.550, r_p =-0.545) at both genotypic and phenotypic levels. Pod width was shown as a significant negative correlation at the genotypic level (r_g = -0.566), but at the phenotypic level (r_p =-0.275) non-significant correlation with vine length.

Association studies exhibited a significant positive correlation between harvest index with pod length (r_g = 0.717, r_p =0.792) and a significant negative correlation with crop duration (r_g = -0.717, r_p = -0.562) days to 50 % flowering (r_g = -0.563, r_p = -0.653), and vine length (r_g = -0.55, r_p = -0.545) at both genotypic and phenotypic levels. Pods per plant and pod width showed a positive but non-significant correlation with the harvest index at both genotypic and phenotypic levels. Pod weight showed a significant positive correlation at the genotypic level (r_g = 0.525), but at the phenotypic level (r_p= 0.418), a non-significant correlation with the harvest index.

At both genotypic and phenotypic levels, the crop duration exhibited a significant positive correlation with vine length (r_g = 0.981, r_p = 0.770) and days to 50 % flowering (r_g = 0.849, r_p =0.505) and a significant negative correlation with pod length (r_g = -0.997, r_p = -0.960), pod weight (r_g = -0.951, r_p = -0.721), pods per plant (r_g = -0.791, r_p = -0.702), and harvest index (r_g = -0.717, r_p =-0.562). Pod width showed a positive correlation, but it is non-significant with crop duration.

Path analysis

Path analysis separates the genotypic correlation into direct and indirect effects, showing each trait's contribution to yield. Selection is most effective when the correlation with yield is due to a trait's direct effect. If driven by an indirect effect, selection should focus on the related trait. When the direct effect is weak or negative, but the correlation is positive, indirect traits should be prioritized. In cases of a negative correlation but strong direct effect, a balanced selection approach is needed (Singh and Kakar, 1977). The direct and indirect effects on yield are represented in Table 2. The genotypic path diagram for yield is depicted in Fig. 1.

Direct effect : The pod weight (1.090) and harvest

Table 2 : Direct and indirect effects of different characters on yield of F_3 families of yard long bean.

	Days to 50% flowering	Pod length	Pod width	Pod weight	Pods per plant	Vine length	Harvest index	Crop duration	Genotypic correlation
Days to 50% flowering	**0.877**	1.455	0.002	-0.734	1.598	-3.248	-0.584	0.007	-0.626
Pod length	-0.837	**-1.525**	0.154	0.826	-1.721	3.176	0.744	-0.008	0.809
Pod width	0.002	-0.295	**0.798**	0.933	-2.713	1.984	0.048	-0.004	0.753
Pod weight	-0.591	-1.156	0.683	**1.09**	-2.923	3.322	0.545	-0.008	0.962
Pods per plant	-0.478	-0.894	0.737	1.085	**-2.937**	2.96	0.455	-0.006	0.922
Vine length	0.814	1.383	-0.452	-1.034	2.482	**-3.502**	-0.57	0.008	-0.871
Harvest index	-0.494	-1.094	0.037	0.572	-1.287	1.925	**1.037**	-0.006	0.691
Crop duration	0.745	1.52	-0.372	-1.037	2.324	-3.434	-0.743	**0.008**	-0.989

Note : Bold diagonal values are direct effects.

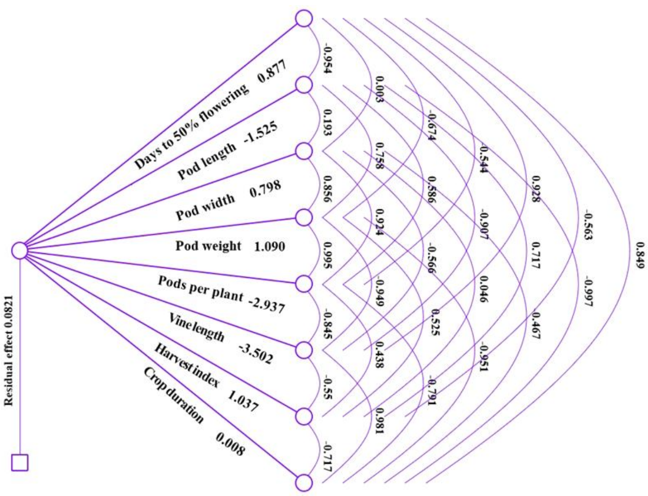

Fig. 1 : Genotypic path diagram for yield in F_3 families of yard long bean.

index (1.037) exhibited a very high direct effect on yield per plant. The highest direct effect on yield per plant was by days to 50 % flowering (0.877), followed by pod width (0.798). The crop duration (0.008) showed a positive but negligible direct effect on yield per plant. Vine length (-3.502), pods per plant (-2.937), and pod length (-1.525) exhibited a negative direct effect on yield per plant.

Indirect effect : The very high positive indirect effect on yield per plant was recorded via vine length by pod length (3.176), followed by pod weight (3.322), pods per plant (2.960), pod width (1.984), and harvest index (1.925), but the crop duration (-3.434) and days to 50% flowering (-3.248) had very high negative indirect effects through the vine length.

Characters like vine length (2.482), crop duration (2.324), and days to 50 % flowering (1.598) recorded very high indirect effects on yield per plant via pods per plant. A very high negative indirect effect on yield per plant was exhibited by pod weight (-2.923), pod width (-2.713), pod length (-1.721), and harvest index (-1.287) through pods per plant.

The crop duration (1.520), days to 50% flowering (1.455), and vine length (1.383) exhibited a very high indirect effect on yield per plant via pod length. A negative but very high indirect effect on yield per plant was by pod weight (-1.156) and harvest index (-1.094), whereas Pods per plant (-0.894) showed a high indirect effect and pod width (-0.295) exhibited moderate indirect effect through pod length.

Characters like pods per plant (1.085) exhibited a very high indirect effect on yield per plant via pod weight. Pod width (0.933), pod length (0.826), and harvest index (0.572) exhibited a high indirect effect on yield per plant via pod weight. A negative but very high indirect effect on yield per plant by harvest index (-1.037) and vine length (-1.034) through pod weight. A negative but high indirect effect on yield per plant was shown by days to 50 % flowering (-0.734) through pod weight.

The pod length (0.744), pod weight (0.545), and pods per plant (0.455) exhibited a high indirect effect on yield per plant via harvest index. A negligible indirect effect by pod width (0.048) on yield per plant through harvest index. A negative but high indirect effect on yield per plant was shown by days to 50% flowering (-0.584) and vine length (-0.570) through the harvest index.

Characters like pods per plant (0.737) and pod weight (0.683) exhibited a high indirect effect on yield per plant via pod width. Pod length (0.154) exhibited a low indirect effect on yield per plant through pod width. Harvest index (0.037) and days to 50 % flowering (0.002) exhibited a negligible indirect effect on yield per plant through pod width. A negative but high indirect effect on yield per plant was shown by vine length (-0.452) and crop duration (-0.372) via pod width.

The vine length (0.814) and crop duration (0.745) showed a high indirect effect on yield per plant via days to 50 % flowering. Pod width (0.002) showed a negligible indirect effect on yield per plant via days to 50 % flowering. A negative but high indirect effect on yield per plant was shown by pod length (-0.837), pod weight (-0.591), harvest index (-0.494) and pods per plant (-0.478) through days to 50% flowering.

Characters like vine length (0.008) and days to 50 % flowering (0.007) exhibited negligible indirect effect on yield per plant via crop duration. A negative negligible indirect effect on yield per plant was exhibited by pod length (-0.008), pod weight (-0.008), pods per plant (-0.006) and pod width (-0.004) through crop duration.

Discriminant function analysis

Discriminant function analysis is a statistical method used to distinguish desirable genotypes from undesirable ones based on a combination of traits. Five families were categorized based on a selection index value developed using 9 characteristics: days to 50% flowering (x_1), Pod length (x_2), Pod width (x_3), Pod weight (x_4), Pods per plant (x_5), Vine length (x_6), Harvest index (x_7), Crop duration (x_8), Yield per plant(x_9). The combination of these traits provides estimates for efficient selection based on indices values.

In this study, the selection index values ranged from 2136.10 to 1797.34 for five F_3 families of yard long bean. The highest values were observed for F_3-1, followed by F_3-3 and F_3-2 (Table 3).

Table 3 : Selection index and ranking of five F_3 families of yard long bean.

Rank	Families	Selection index
1	F_3-1	2136.1003
2	F_3-3	1943.5455
3	F_3-2	1927.5199
4	F_3-5	1823.0041
5	F_3-4	1797.345

Discussion

The study of correlation, path analysis, and discriminant function analysis in the F_3 segregants of yard long bean provides valuable insights into the complex relationships between traits contributing to yield and drought tolerance. As the yard long bean is an essential legume crop valued for its high nutritional content and adaptability to diverse agro-climatic conditions, understanding the genetic and phenotypic associations among traits is pivotal for targeted crop improvement programs.

Correlation analysis elucidates the degree and direction of association between yield and its component traits, offering an initial perspective on their potential impact on yield enhancement. In this study, the genotypic correlation coefficients for various traits with yield were generally higher than the phenotypic ones, indicating a strong genetic association that is less influenced by environmental factors. Positive and negative genotypic correlations are linked to gene linkage in coupling or repulsion phases (Salini *et al*., 2010 and Yeshitila *et al*., 2023).

The current investigation found a significant positive correlation between yield per plant and traits like pod weight, number of pods per plant, pod length, pod width, and harvest index, as also reported by Vanaja *et al.* (2015) in red gram and Baroowa and Gogoi (2016) in black gram. Similarly, Pratap *et al.* (2024) observed these traits in pea. However, negative correlations were noted with crop duration, vine length, and days to 50% flowering, which align with studies by Kanimoli *et al.* (2015) in chickpea, Eswaran and Senthilkumar (2015) in green gram, Bordoloi *et al.* (2018) in black gram, and Ajayi *et al.* (2020) in cowpea.

However, correlation alone does not reveal the direct and indirect contributions of these traits. To address this limitation, path analysis is employed to partition the correlation coefficients into direct effects and indirect effects, thereby highlighting the traits that have a significant and direct influence on yield.

In the current study, characters like pod weight and harvest index had the strongest direct effects on yield per plant, along with days to 50% flowering and pod width. Therefore, selecting for these traits will enhance yield in yard long bean. This aligns with findings from Suma *et al.* (2021), Pornsouriya *et al.* (2022), and Sundar *et al.* (2022). Conversely, vine length, pods per plant, and pod length negatively influenced yield, indicating that selecting against these traits can boost productivity, as observed by Sultana *et al.* (2017) and Pornsouriya *et al.* (2022). Crop duration had a minor positive effect, similar to Degefa *et al.* (2013) in mung bean, and Aliyu *et al.* (2022) and Abha and Meena (2024) in cowpea.

Moreover, discriminant function analysis serves as a powerful multivariate tool for distinguishing superior F_3 segregants based on their trait performance under specific selection criteria. This method aids in identifying distinct groups of genotypes with desirable traits, facilitating effective selection decisions. In this study, the selection index values ranged from 2136.10 to 1797.34 for five F_3 families of yard long bean. The highest values were observed for F_3-1, followed by F_3-3 and F_3-2. Similar results were reported in cowpea by Jivani *et al.* (2016) and Rukhsar *et al.* (2021).

In the context of the current study, the integration of these analytical techniques is expected to provide a robust framework for selecting promising genotypes with higher yield potential.

Conclusion

For yield improvement in yard long bean, traits such as the number of pods per plant, pod weight, pod length, pod width, and harvest index showed a positive correlation with yield per plant. These characteristics can serve as key criteria in the selection process during breeding, especially in segregating generations. Correlation and path coefficient analyses suggest that focusing on these traits could effectively enhance yield. Discriminant function analysis suggests that family F_3-1 has the highest selection index (2136.10) followed by F_3-3 (1943.5455) and F_3-2 (1927.5199). Consequently, the selection of F_3-1, F_3-3 and F_3-2 families exhibiting these traits is expected to contribute to yield improvement in yard long bean, making them valuable candidates for inclusion in future breeding programs.

Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Author contributions

BT contributed to the conception and design of the study. RN carried out the experiments, curated the information and wrote the first draft. Authors have contributed to the draft manuscript revision and have critically reviewed and edited the submitted manuscript.

Data availability

Data is provided in the manuscript.

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