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Genetic evaluation and heterosis studies through diallel crossing for yield and quality in yardlong bean [*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt.]

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Abstract

A diallel breeding programme was carried out to assess heterotic vigour and quality improvement in yardlong bean [*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.] using six genetically diverse parents selected from genetic divergence studies undertaken with 69 genotypes (Arka Mangala, Vyjayanthi, Vellayani Jyothika, Lola, VS 28 and VS 54) and their thirty F_1 hybrids. The parents and hybrids, along with a standard check (Iris Super Long-77), were evaluated in a Randomized Block Design with two replications for pod yield and quality attributes, namely protein content, crude fibre, vitamin C and keeping quality. Wide variability was recorded among the hybrids for all the traits studied. The hybrid $P_1 \times P_3$ recorded the highest pod yield plant⁻¹ (1149.58 g) and protein content (16.90%) together with the lowest crude fibre (4.90%), while $P_1 \times P_6$ exhibited the maximum vitamin C content (22.80 mg 100 g⁻¹) and the longest keeping quality (7.20 days). Most hybrids surpassed the parental mean for nutritional and shelf-life traits, indicating substantial scope for heterosis breeding. The crosses $P_1 \times P_3$, $P_1 \times P_6$ and $P_5 \times P_3$ emerged as the most promising combinations for simultaneous improvement of yield and quality and are recommended for further exploitation in yardlong bean improvement programmes.

Keywords: Yardlong bean, diallel cross, heterosis, pod quality, protein, crude fibre, vitamin C, keeping quality

1. Introduction

Yardlong bean [*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.], also known as asparagus bean or snake bean, is an important warm-season legume vegetable cultivated widely across tropical and subtropical Asia for its long, tender, succulent pods. Besides being a rich and inexpensive source of dietary protein, dietary fibre and vitamins, the crop contributes significantly to household nutritional security and offers remunerative returns to smallholder vegetable growers. Consumer preference for yardlong bean is closely linked to pod quality attributes such as protein content, crude fibre, ascorbic acid concentration and post-harvest shelf life, in addition to pod yield, making simultaneous improvement of yield and quality a key breeding objective.

Heterosis breeding through diallel mating offers an effective route for combining favourable alleles governing yield and quality from diverse parents into superior hybrid combinations, while diallel analysis further permits identification of parents with high combining ability for use in recombination breeding. Although several studies have reported variability for yield and biometric traits in yardlong bean, information on the heterotic performance of quality parameters such as protein, crude fibre, vitamin C and keeping quality in a systematic diallel set remains limited. The present investigation was therefore undertaken to evaluate six diverse parents and their thirty F_1 hybrids for pod yield and key quality traits, and to identify superior hybrid combinations with potential for commercial exploitation and future recombination breeding in yardlong bean.

2. Materials and Methods

The present investigation was carried out at the College Farm, Department of Horticulture, Pandit Jawaharlal Nehru College of Agriculture and Research Institute (PAJANCOA & RI), Karaikal, Union Territory of Puducherry, India, situated between 10°49' S-11°01' N latitude and 78°43' W-79°52' E longitude, at an altitude of 4 m above mean sea level. The experimental soil was sandy loam with medium fertility, and the site experiences a tropical climate with a hot summer. The crop was raised under irrigation drawn from a rain-water harvesting pond within the farm.

Six genetically diverse and superior yardlong bean genotypes-Arka Mangala (P₁), Vyjayanthi (P₂), Vellayani Jyothika (P₃), Lola (P₄), VS 28 (P₅) and VS 54 (P₆)-were selected from evaluation studies done with 69 yardlong bean genotypes as parents on the basis of prior variability and genetic divergence studies were intercrossed in a diallel mating design to generate thirty F₁ hybrid combinations. The resulting thirty hybrids, the six parents and a standard commercial check hybrid, Iris Super Long-77 (BigHaat, Bengaluru, Karnataka), were evaluated together in a Randomized Block Design with two replications during Jan-April 2026.

Quality traits: Pod yield plant⁻¹ (g) was recorded from total marketable pod weight harvested per plant. Crude fibre content (%; dry-weight basis) of pods at harvestable maturity was estimated following the acid-alkali digestion procedure of Chopra and Kanwar (1976) [4], wherein the sample was successively digested in dilute sulphuric acid and sodium hydroxide, and the loss in weight on ignition of the dried residue was expressed as percent crude fibre. Protein content (%; fresh-weight basis) of tender pods was determined by the Lowry method as described by Sadasivam and Manickam (1996) [8], based on colour development with alkaline copper sulphate and Folin-Ciocalteu reagent and measurement of absorbance at 660 nm against a bovine serum albumin standard curve. Ascorbic acid content (mg 100 g⁻¹) was estimated by the 2,6-dichlorophenol-indophenol visual titration method of Sadasivam and Manickam (1996) [8], based on the reduction of the blue dye to a colourless leuco-base by ascorbic acid in the sample extract. Keeping quality (days) was recorded as the number of days for which harvested pods, held under ambient room conditions, retained their colour, glossiness and freshness for consumption. The data recorded for all traits were subjected to analysis of variance appropriate to the Randomized Block Design, and treatment means were compared using the critical difference at 5 percent and 1 percent levels of significance.

3. Results and Discussion

Substantial and significant variability was observed among the six parents and thirty F₁ hybrids for pod yield and all the quality traits studied, indicating ample scope for the identification of superior hybrid combinations for commercial exploitation as well as for use as donor parents in recombination breeding.

3.1 Pod yield plant⁻¹ (g)

Mean pod yield plant⁻¹ among the parents ranged from 664.79 g (P₄) to 756.84 g (P₁), with P₁ exceeding the parental mean of 710.72 g. Among the hybrids, values ranged from 901.60 g (P₄ × P₃) to 1149.58 g (P₁ × P₃), the

latter substantially exceeding the hybrid mean of 979.67 g. Nineteen of the thirty hybrids outperformed the hybrid mean for pod yield, with P₁ × P₃ consistently recording the highest yield across the evaluation. Comparable superiority of the best-performing hybrid for pod yield in yardlong bean has been reported by Ratnakumari *et al.* (2023) [7], and a similar magnitude of yield variation among hybrids has been documented by Sherly *et al.* (2025) [9] and Abhimanyu *et al.* (2025) [11] in yardlong bean.

3.2 Protein content (%)

Protein content among the parents varied from 6.48% (P₅) to 13.58% (P₃), with P₃ exceeding the parental mean of 11.06%. Among the hybrids, values ranged from 14.60% (P₅ × P₄) to 16.90% (P₁ × P₃), the latter exceeding the hybrid mean of 15.46%. The majority of hybrids recorded higher protein content than the hybrid mean, reflecting a marked heterotic improvement in nutritional quality over the parental values. Similarly wide protein variability among yardlong bean accessions has been reported by Choi *et al.* (2024) [2], while Quamruzzaman *et al.* (2022) [6] emphasized protein content as an important quality-evaluation criterion in yardlong bean.

3.3 Crude fibre content (%)

Crude fibre among the parents ranged from 4.82% (P₁) to 5.89% (P₄), with P₄ exceeding the parental mean of 5.43%. Among the hybrids, values ranged from 4.90% (P₁ × P₃) to 5.98% (P₂ × P₅); notably, P₁ × P₃ recorded the lowest crude fibre, below the hybrid mean of 5.43%, reflecting a heterotic reduction in fibre content and consequently improved pod tenderness and quality. A comparable heterotic reduction in fibre content has been reported by Quamruzzaman *et al.* (2022) [6] and Sherly *et al.* (2025) [9] in yardlong bean, and by Choi *et al.* (2024) [2] among yardlong bean genotypes.

3.4 Vitamin C content (mg 100 g⁻¹)

Vitamin C content among the parents ranged from 12.15 mg 100 g⁻¹ (P₄) to 18.86 mg 100 g⁻¹ (P₁), with P₁ exceeding the parental mean of 16.69 mg 100 g⁻¹. Among the hybrids, values ranged from 20.19 mg 100 g⁻¹ (P₄ × P₅) to 22.80 mg 100 g⁻¹ (P₁ × P₆), the latter exceeding the hybrid mean of 21.06 mg 100 g⁻¹. Most hybrids recorded higher vitamin C content than the hybrid mean, indicating good potential for improving the antioxidant quality of pods through hybridization. Comparably wide vitamin C variability among yardlong bean accessions has been reported by Choi *et al.* (2024) [2], and a similar range has been highlighted as a quality-improvement target by Quamruzzaman *et al.* (2022) [6].

3.5 Keeping quality (days)

Keeping quality among the parents ranged from 2.79 days (P₂) to 5.61 days (P₁), with P₁ exceeding the parental mean of 4.32 days. Among the hybrids, values ranged from 6.10 days (P₆ × P₁) to 7.20 days (P₁ × P₆), the latter exceeding the hybrid mean of 6.64 days. Most hybrids exceeded the hybrid mean for keeping quality, indicating a marked heterotic improvement in post-harvest shelf life. A comparable range in shelf-life-related quality traits in yardlong bean has been reported by Sherly *et al.* (2025) [9], Quamruzzaman *et al.* (2022) [6], while analogous variability in post-harvest vigour traits has been documented in common bean by Mang'ache *et al.* (2026) [5].

Taken together, the hybrid $P_1 \times P_3$ combined the highest pod yield and protein content with the lowest crude fibre, while $P_1 \times P_6$ exhibited the best combination of vitamin C content and keeping quality, and $P_5 \times P_3$ also performed consistently well across yield and quality traits. These three crosses, arising predominantly from the parent P_1 (Arka Mangala),

which itself was among the superior parents for most quality traits, appear to be the most promising combinations for simultaneous improvement of yield and pod quality and merit further evaluation for possible commercial release or use as base material in recombination breeding programmes in yardlong bean.

Table 1: Mean performance of yardlong bean parents and hybrids for pod yield and quality traits

S. No.	Parents and Hybrids	Pod yield plant ⁻¹ (g)	Protein (percent)	Crude fiber (percent)	Vit C (mg/100 g)	Keeping quality (days)
1	P_1	756.84	12.58*	4.82*	18.86	5.61*
2	P_2	683.76	11.42	5.39*	17.14	2.79
3	P_3	700.94	13.58	5.68	18.35	4.92*
4	P_4	664.79	11.36	5.89	12.15	3.74
5	P_5	731.17	6.48	5.36	12.53	4.21
6	P_6	726.80	9.78	5.58	15.88	4.67*
7	$P_1 \times P_2$	945.25	15.70*	5.40*	20.30*	6.50*
8	$P_1 \times P_3$	1149.58 **	16.90 **	4.90 **	21.50 **	6.89 **
9	$P_1 \times P_4$	912.11	15.30*	5.70*	20.40*	6.50*
10	$P_1 \times P_5$	961.45	15.46*	5.39*	20.98*	6.74*
11	$P_1 \times P_6$	1092.24 **	16.49**	5.13**	22.30**	7.20**
12	$P_2 \times P_1$	930.23	14.70	4.91	20.81	6.40
13	$P_2 \times P_3$	940.68	15.19*	5.30*	21.50*	6.80*
14	$P_2 \times P_4$	997.50*	15.40*	5.70*	20.40*	6.50*
15	$P_2 \times P_5$	971.85	15.71*	5.98*	20.69*	6.81*
16	$P_2 \times P_6$	972.90*	14.74*	5.82*	21.26*	6.48*
17	$P_3 \times P_1$	1090.62**	15.80**	5.10**	20.50**	7.10**
18	$P_3 \times P_2$	938.00	15.00*	5.30*	21.60*	6.80*
19	$P_3 \times P_4$	913.36	15.10*	5.29*	21.00*	6.38*
20	$P_3 \times P_5$	946.00	15.00*	5.60*	20.60*	6.30*
21	$P_3 \times P_6$	962.88*	15.94	5.62	20.43	6.39
22	$P_4 \times P_1$	918.72	15.49*	5.90*	20.38*	6.97*
23	$P_4 \times P_2$	986.48*	15.50*	5.60*	20.40*	6.60*
24	$P_4 \times P_3$	901.60	15.20*	5.60*	20.90*	6.20*
25	$P_4 \times P_5$	972.90*	15.68*	5.39*	20.19*	6.65*
26	$P_4 \times P_6$	919.38	15.69*	5.48*	21.09*	6.69*
27	$P_5 \times P_1$	961.45	15.50*	5.60*	20.30*	6.40*
28	$P_5 \times P_2$	978.12	15.70*	5.30*	20.60*	6.70*
29	$P_5 \times P_3$	1041.60 **	16.00**	5.10**	22.80**	6.90**
30	$P_5 \times P_4$	974.97*	14.60	5.60	20.10	6.70
31	$P_5 \times P_6$	960.48	15.11	5.56	21.18	6.94
32	$P_6 \times P_1$	1061.66**	16.30**	5.00**	22.10**	6.10**
33	$P_6 \times P_2$	961.45*	14.90	5.60	21.10	6.60
34	$P_6 \times P_3$	953.44*	15.30*	5.50*	20.30*	6.70*
35	$P_6 \times P_4$	912.78	15.60*	5.40*	21.10*	6.60*
36	$P_6 \times P_5$	957.90	15.00	5.50	21.30	6.50
37	Check hybrid	1025.19	13.90	6.12	18.92	5.90
	SED	31.18	0.41	0.21	0.46	0.16
	CD (0.05)	62.36	0.83	0.42	0.93	0.32
	CD (0.01)	82.94	1.10	0.55	1.23	0.42
	CV (%)	3.52	3.45	4.21	2.79	3.12
	Mean of parents	710.72	11.06	9.09	16.69	4.32
	Range of parents	664.79-756.84	6.48-13.58	4.82-5.89	12.53-18.86	2.79-5.61
	Mean of hybrids	979.67	15.46	5.43	21.06	6.64
	Range of hybrids	901.60-1149.58	14.60-16.90	4.90-5.98	20.19-22.80	6.10-7.20

4. Conclusion

The present study revealed considerable heterotic potential for pod yield and quality improvement in yardlong bean through diallel hybridization among six diverse parents. The hybrids $P_1 \times P_3$, $P_1 \times P_6$ and $P_5 \times P_3$ emerged as the most promising combinations, recording superior pod yield along with enhanced protein and vitamin C content, reduced crude fibre and improved keeping quality relative to their parents and the standard check. These findings underscore the value of Arka Mangala (P_1) as a superior general combiner for quality traits and support the use of these elite hybrid

combinations, either for direct commercial exploitation after further multi-location testing or as source material for recombination breeding aimed at combining high yield with superior nutritional and post-harvest quality in yardlong bean.

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