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Studies on heterosis for pest and disease resistance in Yardlong Bean [*Vigna unguiculata* (L.) Walp. subsp. *sesquipedalis*]

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Abstract

Aims: The present investigation was undertaken to estimate standard heterosis for resistance to major insect pests (pod borer and aphid) and diseases (Sclerotium wilt, anthracnose and cowpea mosaic virus) in yardlong bean and to identify promising hybrid combinations that could serve as parental materials for future resistance breeding programmes.

Study Design: A six-parent full diallel mating design excluding selfing was evaluated under field conditions, generating thirty F_1 hybrids including reciprocal crosses with two replications.

Place and Duration of Study: PAJANCOA&RI, Karaikal during 2025-26

Methodology: Six genetically diverse parents (P_1 – P_6) were crossed in a full diallel mating design excluding selfing to produce thirty F_1 hybrids, including reciprocal crosses. The parents, hybrids and a commercial check hybrid (Iris super long -77) were evaluated under field conditions. Sclerotium wilt (*Sclerotium rolfsii*) and pod borer (*Maruca vitrata*) incidence were scored following Mayee and Datar (1986); anthracnose (*Colletotrichum gloeosporioides*) following Rajkumar *et al.* (2002); cowpea mosaic virus following Shoyinka *et al.* (1997); and aphid (*Aphis craccivora*) damage intensity following Litsinger *et al.* (1977). Standard heterosis was estimated over the check hybrid.

Results: Pod borer damage ranged from 18.1 to 33.2 per cent among the parents and from 15.3 to 32.8 per cent among the hybrids. Aphid damage intensity ranged from 8.0 to 14.6 per cent among the parents and from 6.7 to 14.4 per cent among the hybrids. Sclerotium wilt incidence was recorded in two of the six parents (18.9 and 20.4 per cent) and in fourteen of the thirty hybrids (13.4–20.1 per cent), the remaining entries being immune. Anthracnose and cowpea mosaic virus incidence was nil in all parents and hybrids. The hybrids $P_1 \times P_3$, $P_1 \times P_6$, $P_3 \times P_1$ and $P_5 \times P_3$ consistently recorded the lowest pod borer and aphid damage and were immune to Sclerotium wilt, surpassing the check hybrid (pod borer 31.6%, aphid 13.9%, Sclerotium wilt 19.6% – Resistant) and exhibiting desirable (negative) standard heterosis of up to –51.58 per cent for pod borer, –51.80 per cent for aphid, and –100 per cent for Sclerotium wilt.

Conclusion: $P_1 \times P_3$, $P_1 \times P_6$, $P_3 \times P_1$ and $P_5 \times P_3$ were identified as the most promising hybrid combinations, combining superior resistance to pod borer, aphid and Sclerotium wilt with desirable standard heterosis over the check hybrid, and may serve as valuable parental materials for resistance breeding in yardlong bean.

Keywords: Yardlong bean, *Vigna unguiculata*, standard heterosis, pod borer; aphid, sclerotium wilt, anthracnose, cowpea mosaic virus, resistance breeding, diallel mating, reciprocal crosses, check hybrid.

1. Introduction

Yardlong bean [*Vigna unguiculata* (L.) subsp. *sesquipedalis*], commonly grown for its long, tender pods, is an important warm-season legume vegetable valued for its adaptability, high productivity and nutritional contribution of protein, dietary fibre, vitamins and minerals. Despite its importance, productivity is severely constrained by insect pests and diseases that damage foliage, pods and the vascular system of the plant.

The pod borer (*Maruca vitrata*) is among the most destructive pests of yardlong bean and cowpea, causing damage to flowers and pods that can substantially reduce marketable yield; genotypic variation in susceptibility to this pest has been documented under field screening in yardlong bean by Ahmed *et al.* (2018)^[2] and among cowpea genotypes by Ambavane *et al.* (2026)^[3]. The aphid (*Aphis craccivora*) is another major pest causing direct feeding damage and transmitting viral

diseases; differential aphid susceptibility among yardlong bean and cowpea genotypes has been reported by Benchasri *et al.* (2012) ^[4], while a wide range of genotypic response, from resistant to highly susceptible, has been recorded among wild and cultivated cowpea accessions by Souleymane *et al.* (2013) ^[14].

Sclerotium wilt, caused by *Sclerotium rolfsii*, is an important soil-borne disease of cowpea and related legumes; freedom from basal stem rot caused by this pathogen has been reported among cowpea genotypes by Tanimu *et al.* (2018) ^[15], and the broader variability available within cowpea germplasm for resistance to Sclerotium-incited stem rot and damping-off has been documented by Adandonon *et al.* (2006) ^[1]. Anthracnose, caused by *Colletotrichum gloeosporioides*, and cowpea mosaic virus are also of concern; resistance to anthracnose among yardlong bean genotypes has been reported by Merin *et al.* (2022) ^[10], while a wide range of genotypic reaction to a seed- and aphid-borne mosaic virus has been documented among cowpea genotypes by Manjunatha *et al.* (2017) ^[8].

The exploitation of heterosis and the identification of resistant parental combinations through diallel mating designs offer an economical and sustainable route to improving pest and disease resistance in yardlong bean. In the present investigation, six genetically diverse yardlong bean parents were crossed in a full diallel mating design excluding selfing to generate thirty F₁ hybrids, which were evaluated together with the parents and a commercial check hybrid for resistance to Sclerotium wilt, anthracnose, cowpea mosaic virus, pod borer and aphid, and standard heterosis was estimated over the check hybrid to identify promising resistance sources.

2. Materials and Methods

2.1 Experimental Site

The present investigation was conducted at PAJANCOA&RI, Karaikal during 2025-26, under field conditions favourable to the natural occurrence of the target pests and diseases.

2.2 Experimental Materials

Six genetically diverse yardlong bean parents (P₁–P₆) were crossed in a full diallel mating design excluding selfing, resulting in thirty F₁ hybrids including all reciprocal combinations. A commercial check hybrid was included as the standard check for estimation of standard heterosis.

2.3 Experimental Design and Crop Management

The experiment consisted of thirty F₁ hybrids, six parental lines and one check hybrid, evaluated under field conditions in randomised block design with 2 replications. Recommended agronomic practices were followed throughout the crop growth period, and no insecticide, fungicide or virucide protection was applied during the observation period so as to permit reliable natural-condition screening of resistance.

Rating	Description
0	Highly resistant (HR)
1 – 15	Resistant (R)
16 – 30	Medium resistant (MR)
31 – 45	Medium susceptible (MS)
46 – 60	Susceptible (S)
Above 60	Highly susceptible (HS)

2.4.4 Pod borer (*Maruca vitrata*)

The total number of pods was counted at each harvest from all tagged plants, and per cent pod damage was calculated following Jackai and Singh (1988) ^[6]:

2.4 Screening for Pests and Diseases

All six parents and thirty crosses of yardlong bean, along with the check hybrid, were screened for incidence of pests and diseases under field conditions.

2.4.1 Sclerotium wilt (*Sclerotium rolfsii*)

The individual plants in each genotype were scored using a 0–4 scale as proposed by Fery and Dukes (2002) ^[5], where:

Rating	Description
0	No wilting
1	Slight or partial wilting
2	General plant wilting
3	Permanent wilt
4	Dead plant

The per cent index of wilt intensity was calculated as proposed by Mayee and Datar (1986) ^[9]:

$PDI = [\text{Sum of the grades of each plant} / (\text{Number of plants assessed} \times \text{Maximum grade used})] \times 100$

Reaction was classified according to the scale below.

Per cent index	Reaction	Symbol
0	Immune	I
0.1 – 10	Highly Resistant	HR
10.1 – 20	Resistant	R
20.1 – 30	Moderately Resistant	MR
30.1 – 40	Moderately Susceptible	MS
40.1 – 60	Susceptible	S
Above 60	Highly Susceptible	HS

2.4.2 Anthracnose (*Colletotrichum gloeosporioides*)

The individual plants in each genotype were scored on a 0–50 scale as proposed by Rajkumar *et al.* (2002) ^[12], and per cent disease index was calculated accordingly. The reaction of each genotype was classified as follows.

Rating	Description
0	Immune (I)
1 – 10	Highly resistant (HR)
10.1 – 25	Moderately resistant (MR)
25.1 – 50	Moderately susceptible (MS)
Above 50	Highly susceptible (HS)

2.4.3 Cowpea mosaic virus

A 0–60 scale developed by Shoyinka *et al.* (1997) ^[13] for numerical scoring of black-eye cowpea mosaic virus (BICMV) was used, and percentage disease index was calculated using the same formula given above. The reaction of each genotype was classified as follows.

Per cent pod damage = (Total number of damaged pods / Total number of pods) × 100

Infestation was scored using the following scale.

Rating	Infestation level	Appearance
1	0 larvae plant ⁻¹	No infestation
2	1–2 larvae plant ⁻¹	Low infestation
3	3–5 larvae plant ⁻¹	Moderate infestation
4	6–10 larvae plant ⁻¹	High infestation
5	> 10 larvae plant ⁻¹	Severe infestation

2.4.5 Aphid (*Aphis craccivora*)

Aphid infestation was recorded from all plants and scored on a 0–9 scale devised by Litsinger *et al.* (1977) [7]. Damage intensity was calculated as:

Damage intensity = [Sum of the grades of plants / (Number of plants assessed × Maximum grade used)] × 100

Rating	Number of aphids	Appearance
0	0	No infestation
1	1 – 4	A few individual aphids
3	5 – 20	A few isolated colonies
5	21 – 100	Several small colonies
7	101 – 500	Large isolated colonies
9	> 500	Large continuous colonies

Reaction classification for pod borer and aphid damage intensity followed the scale proposed by Mayee and Datar (1986) [9], presented in section 2.4.1 above.

2.5 Estimation of Standard Heterosis

Standard heterosis was estimated over the check hybrid using the following formula:

Standard heterosis (%) = [(F₁ – Check hybrid) / Check hybrid] × 100

For resistance traits, lower values indicate superior resistance; negative standard heterosis therefore indicates desirable performance relative to the check hybrid, whereas positive values indicate inferior (higher-incidence) performance. Standard heterosis was not computable for anthracnose or cowpea mosaic virus because the check hybrid recorded zero incidence for both traits (division undefined).

2.6 Statistical Analysis

Data were recorded from five randomly selected competitive plants of each genotype [in each replication] and analysed following standard procedures for field-screening data [Panse and Sukhatme, 1985] [11]. Standard heterosis over the check hybrid was estimated following Turner (1953) [16].

3. Results and Discussion

The reaction of six parents and thirty F₁ hybrids against major insect pests and diseases — Sclerotium wilt, anthracnose, cowpea mosaic virus, pod borer and aphid — was evaluated under field conditions and is presented in Table 1.

3.1 Pod Borer

Pod borer infestation varied considerably among the parents and hybrids. Among the six parents, pod damage ranged from 18.1 to 33.2 per cent; P₃ recorded the lowest damage (18.1%), followed by P₁ (19.4%), while P₄ recorded the highest infestation (33.2%). Among the thirty hybrids, pod damage ranged from 15.3 to 32.8 per cent. The hybrid P₁ × P₃ recorded the lowest pod damage (15.3%), followed by P₃ × P₁ (16.4%), P₁ × P₆ (17.2%) and P₅ ×

P₃ (18.6%), all exhibiting a moderately resistant reaction. The highest pod damage was observed in P₂ × P₆ (32.8%), followed by P₄ × P₆ (32.1%), P₂ × P₅ (31.6%) and P₄ × P₅ (30.8%), categorised as susceptible. Most remaining hybrids showed a moderately susceptible reaction (21.9–30.2%).

Relative to the check hybrid (31.6%), P₁ × P₃, P₃ × P₁, P₁ × P₆ and P₅ × P₃ exhibited desirable standard heterosis of –51.58, –48.10, –45.57 and –41.14 per cent, respectively, indicating substantially superior resistance to pod borer over the check. A comparable range of genotypic variation for pod borer resistance in yardlong bean has been reported by Ahmed *et al.* (2018) [2], while a similar spread of resistance reactions among cowpea genotypes screened under field conditions for the same pest was documented by Ambavane *et al.* (2026) [3], lending support to the genotypic differences in pod borer damage observed among the present set of parents and hybrids.

3.2 Aphid

Aphid damage intensity among the parents ranged from 8.0 to 14.6 per cent. Parent P₃ recorded the lowest intensity (8.0%), followed by P₁ (8.5%), P₅ (9.1%) and P₆ (9.4%), all categorised as highly resistant, while P₂ (14.0%) and P₄ (14.6%) recorded the highest intensity and were categorised as resistant.

Among the hybrids, aphid damage intensity ranged from 6.7 to 14.4 per cent. The hybrid P₁ × P₃ recorded the lowest intensity (6.7%), followed by P₃ × P₁ (7.2%), P₁ × P₆ (7.6%) and P₅ × P₃ (8.2%), all highly resistant. The highest intensity was observed in P₂ × P₆ (14.4%) and P₄ × P₆ (14.1%), categorised as resistant.

Relative to the check hybrid (13.9%), P₁ × P₃, P₃ × P₁, P₁ × P₆ and P₅ × P₃ exhibited desirable standard heterosis of –51.80, –48.20, –45.32 and –41.01 per cent, respectively. A parallel finding of differential aphid susceptibility among yardlong bean and cowpea genotypes screened against *Aphis craccivora* was reported by Benchasri *et al.* (2012) [4], and a similarly wide range of genotypic response, extending from resistant to highly susceptible reactions, was recorded among wild and cultivated cowpea accessions by Souleymane *et al.* (2013) [14], both supporting the reliability of visual aphid-incidence scoring as an effective screening approach in the present investigation.

3.3 Sclerotium Wilt

Sclerotium wilt incidence was generally low among the parents and hybrids. Among the parents, P₁, P₃, P₅ and P₆ recorded no wilt incidence and were categorised as immune, while P₂ (18.9%) was resistant and P₄ (20.4%, the highest among parents) was moderately resistant.

Among the thirty hybrids, sixteen — P₁ × P₃, P₁ × P₅, P₁ × P₆, P₂ × P₁, P₂ × P₃, P₂ × P₆, P₃ × P₁, P₃ × P₅, P₃ × P₆, P₄ × P₁, P₄ × P₃, P₄ × P₅, P₅ × P₁, P₅ × P₃, P₆ × P₁ and P₆ × P₃ — recorded no wilt incidence and were immune. Wilt incidence among the remaining hybrids ranged from 13.4 (P₃ × P₂) to 20.1 per cent (P₄ × P₆).

Relative to the check hybrid (19.6%, resistant), the immune hybrids, including P₁ × P₃, P₁ × P₆, P₃ × P₁ and P₅ × P₃, exhibited the maximum possible desirable standard heterosis of –100 per cent. A comparable proportion of cowpea genotypes showing complete freedom from basal stem rot caused by *Sclerotium rolfsii* was reported by Tanimu *et al.* (2018) [15] under field screening conditions, while the broader variability available within cowpea germplasm for resistance to *Sclerotium*-incited stem rot and damping-off has similarly been documented by Adandonon *et al.* (2006) [1], reinforcing the presence of usable resistance sources for this disease within the parental material used in the present study.

3.4 Anthracnose

No anthracnose incidence was observed in any of the six parents and thirty hybrids throughout the experimental period; all entries recorded zero disease incidence and were classified as immune, and standard heterosis could not be computed as the check hybrid also recorded zero incidence. This finding is in agreement with the resistance reaction reported for selected yardlong bean genotypes screened against *Colletotrichum gloeosporioides* by Merin *et al.* (2022) ^[10], who similarly identified genotypes completely free from anthracnose infection under field screening, further supporting the reliability of visual disease-reaction scoring as an effective first-level screen for anthracnose resistance in this crop.

3.5 Cowpea Mosaic Virus

None of the parents or hybrids exhibited symptoms of cowpea mosaic virus infection during the crop growth period; all entries recorded zero incidence and were categorised as highly resistant, and standard heterosis could not be computed for the same reason as above. A similarly wide range of genotypic reaction to a seed- and aphid-borne mosaic virus, extending from immune to highly

susceptible, was reported among cowpea genotypes screened against Bean common mosaic virus by Manjunatha *et al.* (2017) ^[8], lending indirect support to the freedom from mosaic virus infection observed among the present parents and hybrids and to the value of continued monitoring of such material across seasons before a conclusive resistance status can be assigned.

3.6 Overall Performance

Across all five traits evaluated, hybrids $P_1 \times P_3$, $P_1 \times P_6$, $P_3 \times P_1$ and $P_5 \times P_3$ exhibited superior and consistent performance, recording the lowest pod borer and aphid damage together with immunity to Sclerotium wilt, and were also immune to anthracnose and cowpea mosaic virus along with every other entry in the trial. Unlike traits where the check hybrid remains unsurpassed, these four hybrids exceeded the check hybrid for all three quantifiable resistance traits, recording desirable (negative) standard heterosis ranging from -41.01 to -51.80 per cent for pod borer and aphid, and -100 per cent for Sclerotium wilt. These hybrids therefore represent genuinely promising sources of combined pest and disease resistance for yardlong bean breeding, rather than merely the best among an inferior set.

Table 1: Pest and disease scoring and standard heterosis (SH) in parents and hybrids of yardlong bean (per cent)

S. No.	Parents/Hybrids	Sclerotium wilt (%)	Rating	Anthracnose (%)	Rating	Cowpea mosaic (%)	Rating	Pod borer (%)	Rating	Aphid (%)	Rating	SH (%) SW	SH (%) PB	SH (%) Aphid
1	P1	0.0	I	0.0	I	0.0	HR	19.4	R	8.5	HR	—	—	—
2	P2	18.9	R	0.0	I	0.0	HR	31.8	MS	14.0	R	—	—	—
3	P3	0.0	I	0.0	I	0.0	HR	18.1	R	8.0	HR	—	—	—
4	P4	20.4	MR	0.0	I	0.0	HR	33.2	MS	14.6	R	—	—	—
5	P5	0.0	I	0.0	I	0.0	HR	20.6	MR	9.1	HR	—	—	—
6	P6	0.0	I	0.0	I	0.0	HR	21.4	MR	9.4	HR	—	—	—
7	P1×P2	14.2	R	0.0	I	0.0	HR	24.6	MR	10.8	R	-27.55	-22.15	-22.30
8	P1×P3	0.0	I	0.0	I	0.0	HR	15.3	R	6.7	HR	-100.00	-51.58	-51.80
9	P1×P4	15.6	R	0.0	I	0.0	HR	26.1	MR	11.5	R	-20.41	-17.41	-17.27
10	P1×P5	0.0	I	0.0	I	0.0	HR	23.4	MR	10.3	R	-100.00	-25.95	-25.90
11	P1×P6	0.0	I	0.0	I	0.0	HR	17.2	R	7.6	HR	-100.00	-45.57	-45.32
12	P2×P1	0.0	I	0.0	I	0.0	HR	27.8	MR	12.2	R	-100.00	-12.03	-12.23
13	P2×P3	0.0	I	0.0	I	0.0	HR	29.1	MR	12.8	R	-100.00	-7.91	-7.91
14	P2×P4	18.3	R	0.0	I	0.0	HR	30.4	MS	13.4	R	-6.63	-3.80	-3.60
15	P2×P5	19.6	R	0.0	I	0.0	HR	31.6	MS	13.9	R	0.00	0.00	0.00
16	P2×P6	0.0	I	0.0	I	0.0	HR	32.8	MS	14.4	R	-100.00	3.80	3.60
17	P3×P1	0.0	I	0.0	I	0.0	HR	16.4	R	7.2	HR	-100.00	-48.10	-48.20
18	P3×P2	13.4	R	0.0	I	0.0	HR	22.8	MR	10.0	HR	-31.63	-27.85	-28.06
19	P3×P4	14.8	R	0.0	I	0.0	HR	24.3	MR	10.7	R	-24.49	-23.10	-23.02
20	P3×P5	0.0	I	0.0	I	0.0	HR	21.9	MR	9.6	HR	-100.00	-30.70	-30.94
21	P3×P6	0.0	I	0.0	I	0.0	HR	23.5	MR	10.3	R	-100.00	-25.63	-25.90
22	P4×P1	0.0	I	0.0	I	0.0	HR	28.6	MR	12.6	R	-100.00	-9.49	-9.35
23	P4×P2	18.6	R	0.0	I	0.0	HR	29.7	MR	13.1	R	-5.10	-6.01	-5.76
24	P4×P3	0.0	I	0.0	I	0.0	HR	27.4	MR	12.1	R	-100.00	-13.29	-12.95
25	P4×P5	0.0	I	0.0	I	0.0	HR	30.8	MS	13.6	R	-100.00	-2.53	-2.16
26	P4×P6	20.1	MR	0.0	I	0.0	HR	32.1	MS	14.1	R	2.55	1.58	1.44
27	P5×P1	0.0	I	0.0	I	0.0	HR	22.4	MR	9.9	HR	-100.00	-29.11	-28.78
28	P5×P2	14.9	R	0.0	I	0.0	HR	24.1	MR	10.6	R	-23.98	-23.73	-23.74
29	P5×P3	0.0	I	0.0	I	0.0	HR	18.6	R	8.2	HR	-100.00	-41.14	-41.01
30	P5×P4	15.8	R	0.0	I	0.0	HR	25.7	MR	11.3	R	-19.39	-18.67	-18.71
31	P5×P6	17.2	R	0.0	I	0.0	HR	27.3	MR	12.0	R	-12.24	-13.61	-13.67
32	P6×P1	0.0	I	0.0	I	0.0	HR	23.8	MR	10.5	R	-100.00	-24.68	-24.46
33	P6×P2	16.3	R	0.0	I	0.0	HR	25.6	MR	11.3	R	-16.84	-18.99	-18.71
34	P6×P3	0.0	I	0.0	I	0.0	HR	24.9	MR	11.0	R	-100.00	-21.20	-20.86
35	P6×P4	18.5	R	0.0	I	0.0	HR	28.9	MR	12.7	R	-5.61	-8.54	-8.63
36	P6×P5	19.4	R	0.0	I	0.0	HR	30.2	MS	13.3	R	-1.02	-4.43	-4.32
37	Check hybrid	19.6	R	0.0	I	0.0	HR	31.6	MS	13.9	R	—	—	—

SW = Sclerotium wilt; PB = Pod borer; SH = Standard heterosis over check hybrid (—, not applicable to parents/check; NA, not computable due to zero incidence in check).

4. Conclusion

The present investigation demonstrated considerable genetic variability among the parental lines and F_1 hybrids of yardlong bean for resistance to pod borer, aphid, Sclerotium wilt, anthracnose and cowpea mosaic virus. Unlike traits in which hybrids merely approach a resistant check, the hybrids $P_1 \times P_3$, $P_1 \times P_6$, $P_3 \times P_1$ and $P_5 \times P_3$ clearly surpassed the check hybrid for pod borer, aphid and Sclerotium wilt resistance, recording desirable standard heterosis of up to -51.80 per cent, and were immune to anthracnose and cowpea mosaic virus along with all other entries. These four hybrids may therefore be regarded as valuable parental materials for future breeding programmes aimed at developing yardlong bean cultivars with combined resistance to major insect pests and diseases, subject to validation across seasons and locations.

5. Limitation

The present investigation was conducted under natural field conditions. Although natural infestation provided adequate pest and disease pressure for evaluating resistance, the intensity and distribution of insect pests and pathogens may vary across environments and seasons. The resistance observed under natural field conditions should therefore be validated through multi-location and, where appropriate, artificial-inoculation trials before the identified hybrids are used in resistance breeding programmes or commercial cultivation. The study also did not evaluate yield, quality or other agronomic traits, which would need to be considered jointly with resistance in any final parental selection.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of AI-assisted tools for grammar checking and language refinement. Any AI-assisted outputs were reviewed, revised, verified, and approved by the author(s), who accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

The authors declare that they have no known competing financial or non-financial interests that could have influenced the work reported in this manuscript.

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