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RESEARCH ARTICLE

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Genetic Characterization of Soybean (*Glycine max* L.) Genotypes for Yield, Maturity and Rust Resistance

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ABSTRACT

Background: Breeding effort was attempted to identify the potential lines, which will flower and mature earlier with high pod yield potential coupled with rust resistance.

Methods: To achieve the objectives, three varieties were selected. DSb 23 is highly resilient to rust with high pod yield potential but takes too long to mature, whereas, MACS 1575 and MACS 1460 mature earlier but these were low yielder and highly susceptible to rust. To identify superior genotypes having desired characters, crossing was done *viz.,* DSb 23 × MACS 1575 (Cross 1) and DSb 23 × MACS 1460 (Cross 2).

Result: Selection was practised in each generation and evaluated for earliness, rust resistance and productivity traits. PCV and GCV values were high for pod yield followed by moderate for productive pods/plant, test weight, plant height and high heritability coupled with high genetic advance over mean was enumerated for productive pods/plant, test weight, plant height and pod yield in both the crosses from segregating to advanced generation. Hence, simple selection scheme would be sufficient for these traits to bring genetic improvement in desired direction. The potential lines identified in F_5 generation based on early flowering, rust resistance and pod yield attributing traits were appraised in multilocation trial to assess their stability performance before releasing as elite genotype and can also be further used as parents in breeding programme to develop early flowering, high yielding and rust resistant genotypes.

Key words: Genetic advance, Genotypic coefficient of variation, Phenotypic coefficient of variation, Soybean rust.

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is considered as “Yellow Jewel” and “Great Treasure” for its nutrition value. It contains about 40 % protein, 20 % oil and 80% soybean meal, as well as eight essential amino acids. It is high in lysine, as well as vitamins A, B and D. Because of its many uses, such as animal feed, biofuel, fertiliser, cleaning products, cosmetics, candle wax and a protein source through soymilk, tofu and other products, it is also acknowledged as the “Golden Bean” and “Miracle Crop” of the twenty-first century.

Globally, India holds the fourth position in soybean cultivation with an area of 13.2 million hectares and ranks fifth in production, yielding 11.87 million tonnes. The national average productivity stands at approximately 0.90 tonnes per hectare (Anonymous, 2023a). In Karnataka, for the year 2023-24, soybean was cultivated over 4.077 lakh hectares, producing 3.87 lakh tonnes with an average productivity of 0.95 tonnes per hectare. Among the districts, Bidar accounted for the largest share of the soybean area (48.70%), followed by Belagavi (26.10%) and Dharwad (10.47%) (Anonymous, 2023b). Limits in the area, production and productivity scenario of soybean was observed in recent years due to unavailability of biotic/abiotic stress resilient genotypes with high yield potential and early maturity. Soybean rust, caused by *Phakopsora pachyrhizi*, is a devastating disease that can lead to yield losses of up to 100%. The best solution for increasing area under soybean cultivation is the development of genotypes having combination of all these traits.

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An inclusive spectrum of variation is expected to be shown by progenies derived from a set of diverse crosses, thereby providing a vast scope for isolating high yielding segregants. To rally the production potential of soybean, best solution is selection of superior lines in early segregating generations and advanced to next filial generations for the development of high yielding, early maturing and rust resistance varieties. This requires precise evidence on the nature and degree of genetic variation present in soybean and breeder has to formulate criteria for isolating superior genotypes from both segregating generations and advanced generations.

JS 335 is most promising variety which covers more than 80% of the soybean cultivation area in Karnataka. It is high yielding coupled with early maturing and agronomically superior variety but highly susceptible to rust disease. Though farmers suffer from heavy yield loss due to rust, they still cultivate JS 335 as it matures within 85-90 days. The improved genotypes of soybean are DSb 21 and DSb 23 which are high yielding and rust resistant varieties. However, these are late in maturity compared to JS 335 and hence farmers prefer JS 335 over these two improved varieties. In this direction, there is a scope to identify genotypes with high yield coupled with earliness and rust resistance, which will be boon to farmers.

Keeping the aforesaid views, an effort has been made with the following objectives

1 To study the extent of variability created in the early segregating generation to advanced generation for earliness and yield related traits.
2 To screen the segregating and advanced generation for rust resistance.

MATERIALS AND METHODS

With a purpose to identify high yielding, early maturing and rust resistance genotypes, DSb 23 was crossed with MACS 1575 and MACS 1460 during *Kharif* 2019 in AICRP on soybean, main agricultural research station, UAS, Dharwad. DSb 23 is highly resilient to rust with high yield potential, but it will take around 95-100 days to mature and it is developed from U A S, Dharwad. MACS 1575 and MACS 1460 are the genotypes from Agharkar Research Institute, Pune, Maharashtra, which mature in 80-85 days but are susceptible to rust and low yielders compared to DSb 23.

The first filial generation of both the crosses were grown in *kharif* 2020. Two hundred seventy-four seeds from cross 1 and four hundred eighty seeds in cross 2 were harvested in first generation and evaluated in an un-replicated trial during *kharif* 2021 under rainfed condition, which is second filial generation. Selection was progressed in both the crosses for early maturity, rust resistance and yield ascribing traits. Among 274 and 480 F_2 populations, 61 genotypes from cross 1 and 57 genotypes from cross 2 were selected based on our objective and advanced to third filial generation, which were evaluated in plant to progeny rows in augmented design during summer 2022.

Among F_3 generation, 22 genotypes from cross 1 and 14 genotypes from cross 2 were selected based on their superior performance compared to superior checks, JS 335 and DSb 21. Superior F_4 families of both the crosses selected from F_3 generation, were assessed in RCBD during *kharif* 2022 for earliness, rust resistance and yield assigning traits.

From the analysis of F_4 generation, 18 genotypes from cross 1 and 12 genotypes in cross 2 were selected based on their superiority and were further evaluated in summer 2023 under RCBD design for identification of high seed yielding genotypes combined with early maturity and rust resistance.

RESULTS AND DISCUSSION

Mean performance of the parents and checks for different characters in soybean is given in Table 1. The values of mean, minimum and maximum of quantitative traits of cross 1 (DSb 23 × MACS 1575) and cross 2 (DSb 23 × MACS 1460) from segregating generation to advanced generation are given in Table 2 and Table 3. The phenotypic coefficient of variation, genotypic coefficient of variation, heritability and genetic advance over mean from segregating generation to advanced generation are presented in Table 4 and Table 5 respectively.

Days to 50% flowering

In second filial generation, the overall mean of days to 50% flowering in cross 1 (DSb 23 × MACS 1575) was 41 days, whereas overall mean number of days taken for flowering in plants of cross 2 (DSb 23 × MACS 1460) was 40 days. Whereas, in F_5 generation, mean of 50% flowering took around 36 days in cross 1 and 37 days in cross 2. Plant number 7-1, 178-2 and 38-2 of cross 1 were earliest to flower (35 days). Plant number 60-2 and 72-1 of cross 2 flowered at 36 days followed by parent MACS 1575 (38 days).

The phenotypic and genotypic coefficient of variation in both the crosses were moderate in F_2 generation. High heritability entailed with moderate genetic advance over mean was registered for 50% flowering in both the crosses from segregating generation to advanced generation indicates this trait is governed by both additive and non-additive gene action. Similar result was obtained by Osekita and Olorunfemi, (2014).

Days to maturity

The overall mean days taken to attain maturity in cross 1 (DSb 23 × MACS 1575) and cross 2 (DSb 23 × MACS 1460) was in the range of 80 to 112 days in cross 1 and 70 to 110 days in cross 2. In advanced generation, cross 1 and cross 2 plants took around 89 days and 93 days to attain physiological maturity. In cross 1, plant number 178-2 and 38-2 of cross 1 were earliest to mature (87 days) followed by 7-1 (88 days). Plant number 60-2 and 72-1 of cross 2 matured at 93 days respectively.

Table 1: Mean performance of the parents and checks for different characters in soybean.

Parents/ Checks	Days to 50% flowering	Days to maturity	Plant height (cm)	Pods per plant	100 seed weight (g)	Seed yield per plant (g)	Seed yield per plot (kg)
DSb 23	45	95	50.40	74.60	12.80	28.50	01.34
MACS 1575	38	84	41.00	38.00	13.70	14.70	00.96
MACS 1460	39	86	43.20	44.20	13.30	15.20	01.03
JS 335 (check)	40	88	50.40	67.80	10.20	18.10	01.18
DSb 21 (check)	42	91	55.60	79.60	13.10	26.10	01.36

Table 2: Per se performance and range in F_2 to F_5 generations for six quantitative characters in Cross 1 (DSb 23 × MACS 1575) of soybean.

Traits	Generation	Mean	Range	
			Min	Max
Days to 50% flowering	F_2	41.00	37.00	50.00
	F_3	40.00	32.00	47.00
	F_4	36.00	34.00	45.00
	F_5	36.00	34.00	45.00
Days to maturity	F_2	95.00	84.00	112.00
	F_3	92.00	83.00	103.00
	F_4	89.00	81.00	97.00
	F_5	89.00	82.00	95.00
Plant height (cm)	F_2	43.85	13.00	76.00
	F_3	44.07	18.00	64.00
	F_4	46.80	24.80	52.90
	F_5	48.05	21.50	56.75
Number of pods per plant	F_2	66.00	6.00	160.00
	F_3	102.00	56.00	163.00
	F_4	129.00	79.00	168.00
	F_5	131.00	82.00	175.00
100 seed weight (g)	F_2	11.43	6.50	14.50
	F_3	12.85	6.74	13.96
	F_4	13.26	10.70	14.95
	F_5	14.09	11.65	15.95
Seed yield	F_2 (g/plant)	16.50	0.50	42.50
	F_3 (g/plant)	17.51	10.12	45.72
	F_4 (kg/plot)	01.37	00.93	02.21
	F_5 (kg/plot)	01.46	00.97	02.32

Table 3: Per se performance and range in F_2 to F_5 generations for six quantitative characters in Cross 2 (DSb 23 × MACS 1460) of soybean.

Traits	Generation	Mean	Range	
			Min	Max
Days to 50% flowering	F_2	40.00	35.00	45.00
	F_3	39.00	34.00	46.00
	F_4	38.00	36.00	44.00
	F_5	37.00	35.00	44.00
Days to maturity	F_2	95.00	70.00	110.00
	F_3	94.00	85.00	106.00
	F_4	92.00	82.00	98.00
	F_5	93.00	83.00	98.00
Plant height (cm)	F_2	41.28	16.00	60.00
	F_3	44.91	28.00	67.26
	F_4	48.07	42.05	54.20
	F_5	49.88	44.35	57.10
Number of pods per plant	F_2	74.00	6.00	175.00
	F_3	110.00	70.00	177.00
	F_4	135.00	83.00	180.00
	F_5	139.00	83.00	181.00
100 seed weight (g)	F_2	10.34	6.50	14.50
	F_3	11.48	10.25	14.96
	F_4	14.51	12.45	15.45
	F_5	14.57	12.60	15.90
Seed yield	F_2 (g/plant)	18.71	1.00	45.00
	F_3 (g/plant)	20.57	10.00	47.96
	F_4 (kg/plot)	01.87	00.96	02.61
	F_5 (kg/plot)	01.95	00.98	02.87

Table 4: Estimates of variability parameters in F_2 to F_5 generation for six quantitative traits in Cross 1 (DSb 23 × MACS 1575) of soybean.

Traits	Generation	PCV	GCV	h^2	GAM
Days to 50% flowering	F_2	15.09	14.77	75.94	17.49
	F_3	8.01	7.85	78.11	15.86
	F_4	06.53	05.72	81.60	10.31
	F_5	06.85	06.20	85.99	11.57
Days to maturity	F_2	11.57	10.73	70.06	08.08
	F_3	6.88	6.58	75.60	09.97
	F_4	03.17	02.85	80.39	05.26
	F_5	03.10	02.48	82.87	04.07
Plant height (cm)	F_2	24.03	23.07	92.15	45.62
	F_3	25.67	24.59	86.15	28.59
	F_4	22.64	20.37	88.60	39.50
	F_5	21.94	20.27	92.40	40.14
Number of pods per plant	F_2	45.59	44.43	84.98	89.19
	F_3	32.82	29.28	79.08	46.71
	F_4	17.76	16.28	84.08	30.75
	F_5	15.29	14.35	88.07	27.74
100 seed weight (g)	F_2	18.96	14.34	67.15	34.32
	F_3	17.89	17.62	66.98	31.74
	F_4	09.32	07.52	70.24	48.49
	F_5	09.14	07.54	68.03	42.81
Seed yield	F_2 (g/plant)	56.12	53.49	90.87	105.05
	F_3 (g/plant)	22.90	21.12	85.04	40.13
	F_4 (kg/plot)	21.70	20.81	91.99	41.12
	F_5 (kg/plot)	22.08	21.18	91.97	41.84

Table 5: Estimates of variability parameters in F_2 to F_5 generation for six quantitative traits in Cross 2 (DSb 23 × MACS 1460) of soybean.

Traits	Generation	PCV	GCV	h^2	GAM
Days to 50% flowering	F_2	19.19	18.88	66.82	37.15
	F_3	6.34	6.18	74.73	12.38
	F_4	05.27	04.28	75.78	07.15
	F_5	05.51	04.49	86.28	07.53
Days to maturity	F_2	12.44	11.70	72.37	08.93
	F_3	6.79	6.63	75.35	06.34
	F_4	04.10	03.86	84.46	07.48
	F_5	04.21	03.66	88.71	09.49
Plant height (cm)	F_2	18.26	15.80	74.87	48.17
	F_3	19.77	13.03	69.46	37.69
	F_4	07.91	06.71	71.94	41.72
	F_5	08.92	07.36	78.14	52.52
Number of pods per plant	F_2	40.50	39.65	75.85	79.97
	F_3	30.70	19.49	80.34	25.50
	F_4	16.52	15.72	88.58	30.83
	F_5	17.38	16.56	90.76	32.50
100 seed weight (g)	F_2	18.53	14.11	57.99	38.13
	F_3	22.99	20.85	52.21	32.94
	F_4	07.12	05.15	52.30	32.68
	F_5	07.73	06.10	59.43	41.94
Seed yield	F_2 (g/plant)	58.34	56.48	80.73	44.64
	F_3 (g/plant)	24.47	22.35	83.39	42.05
	F_4 (kg/plot)	28.78	27.75	92.96	55.12
	F_5 (kg/plot)	32.24	31.41	94.92	63.03

Low to moderate PCV and GCV values were registered from F_2 to F_5 generation for days to maturity in both the crosses. However, high heritability associated with low genetic advance over mean was observed in both the crosses from F_2 to F_5 generation indicates this character is governed by non-additive gene action. Similar consequences were obtained by Baraskar *et al.* (2013); Chandrawat *et al.* (2017); Malek *et al.* (2014).

Plant height (cm)

Cross 1 (DSb 23 × MACS 1575) chronicled the overall mean of 43.85 cm for plant height, whereas in cross 2 (DSb 23 × MACS 1460), it was around 41.28 cm respectively in second filial generation. However, in fifth filial generation, cross 1 and cross 2 genotypes recorded 48.05 cm and 49.88 cm.

The lines of cross 1 recorded high PCV and GCV values for plant height throughout the generation. But in cross 2, PCV and GCV values were moderate in segregating generation and becomes low in advanced generation. High heritability coupled with high genetic advance over mean was recorded in both the crosses from segregating to advanced generation. Hence, this result was also confirmed by Jain *et al.* (2018) and Bairagi *et al.* (2023).

Productive pods per plant

The data revealed high variability among the lines of both the crosses for this trait**.** The average productive pods/plant was 66.00 in cross 1 with a range 6 to 160, whereas in the cross 2 range values were 6 to 175 with a mean value of 74. However, in advanced generation, cross 1 and cross 2 registered a maximum of 131.00 and 139.00 average productive pods/ plant. Plant number 21-7 of cross 2 recorded highest number of pods (181.00 pods) followed by plant number 92-1 and 58-1 (176.00 pods) of cross 2 in F_2 generation.

The values of PCV, GCV and heritability coupled with genetic advance over mean were high in both the crosses from F_2 to F_5 generation for productive pods/plant. Similar out-turn was reported by Akram *et al.* (2016), Jain *et al.* (2018), Bairagi *et al.* (2023) and Spoorthi *et al.* (2024).

Test weight (g)

In F_2 generation, the mean of test weight in cross 1 was 11.43 g with a wide range of 6.5 g to 15.5 g and in cross 2 the mean value was 10.34 g with a range of 6.5 g to 14.5 g. In F_5 generation, genotypes of cross 1 recorded mean value of 14.09 g and genotypes of cross 2 showed mean value of 14.57 g respectively.

The genotypes of both the crosses from segregating generation to advanced generation registered high values of phenotypic coefficient of variation, genotypic coefficient of variation, heritability coupled with genetic advance over mean. Similar outcomes were registered by Jain *et al.* (2018) and Jain *et al.* (2015).

Pod yield per plant or per plot

Pod yield per plant (g) varied greatly from 0.5 g to 42.5 g with a mean value of 16.50 g in cross 1 whereas in cross 2 mean value was 18.71 g with a range of 1 g to 45 g in F_2 generation. In F_5 generation, lines of cross 1 and cross 2 registered mean pod yield value of 1.46 kg/plot and 1.95 kg/plot respectively. High magnitude of GCV observed for grain yield indicates the presence of wide variation to be allowed for further improvement by selection (Jandong *et al.,* 2020). These results are in contract with the findings by Hakim *et al.* (2014), Mahbub *et al.* (2015).

The values of PCV, GCV, heritability coupled with genetic advance over mean were high in both the crosses from early to advanced generation for pod yield. Amit *et al.* (2014); Savita and Koti (2016) and Spoorthi *et al.* (2024). confer the same results.

The differences in the magnitude of PCV and GCV observed in both the generations of two crosses was very meagre for all the characters studied and similar findings were registered by Malek *et al.* (2014). Akram *et al.* (2016) stated that selection based on those characters, which have low influence of the environmental factors would be effective. Similar findings of small differences between the PCV and GCV values were reported by Mahbub *et al.,* 2015 and Jain *et al.* (2018).

From the F_2 to F_5 generations, there was a consistent decrease in the number of days to 50% flowering and days to maturity in both crosses. This trend aligns with our breeding objective of selecting early-maturing lines that also exhibit favourable traits contributing to higher seed yield. As a result, the values of independent traits associated with seed yield showed a progressive increase across generations.

Screening the F_2 generation and F_4 generation for rust resistance

The two generations were screened for rust resistance during *kharif* 2021 and 2022. The rust reaction of three parents revealed that, parent DSb 23 showed resistant reaction, whereas other two parents *viz.,* MACS 1575 and MACS 1460 were highly susceptible to rust. Rust reaction of parents and checks are given in Table 6. Patil *et al.* (2004); Basavaraja *et al.* (2012); Kurundkar *et al.* (2011), Inayati and Yusnawan (2016) and Immadi *et al.* (2022) characterized soybean genotypes for rust reaction under natural and green house conditions and classified them as resistant and susceptible lines.

The progenies derived from two crosses *i.e.,* 274 plants from cross 1 and 480 progenies from cross 2 were screened for rust disease under natural epiphytotic condition during *kharif* 2021. 66 plants out of 274 plants showed highly resistant reaction (rust score=1) to rust and 127 plants exhibited moderate resistance (rust score=3) to rust in cross 1. Whereas in cross 2, 133 plants out of 480 plants exhibited highly resistant reaction (rust score=1) and 208 plants exhibited moderate resistant (rust score=3) reaction under natural epiphytotic condition. Rust reaction of F_2 plants under natural epiphytotic condition in cross 1 and cross 2 of soybean is given in Table 7.

In F_2 generation, 61 plants from cross 1 and 57 plants from cross 2 were selected based on earliness, rust resistance and yield attributing traits. These 118 genotypes were raised in summer 2022. Due to lower disease incidence, we could not able to screen the plants of both the crosses for rust disease. In F_4 generation, 22 lines from cross 1 and 14 lines from cross 2 were selected based on the yield, earliness and screened for rust disease under natural epiphytotic condition in *kharif* 2022. Among the 22 genotypes tested, none of the genotypes recorded highly resistant reaction to rust and fourteen genotypes (129-12, 7-1, 9-4, 178-2 and 176-1) exhibited moderately resistant, seven genotypes showed moderately susceptible and one genotype registered susceptible reaction to rust as depicted in Table 8.

Table 6: Rust reaction of parents and checks in soybean.

Parents/Checks	Rust score	Rust reaction
DSb23	1	Highly resistant (HR)
MACS1575	9	Highly susceptible (HS)
MACS1460	9	Highly susceptible (HS)
JS335	9	Highly susceptible (HS)
DSb21	1	Highly resistant (HR)

Table 7: Rust reaction of F_2 plants under natural epiphytotic condition in cross 1 and cross 2 of soybean.

Rust reaction	Number of plants	
	Cross 1	Cross 2
Total number of plants screened	274	480
Highly resistant (HR)	66	133
Moderately resistant (MR)	127	208
Moderately susceptible (MS)	21	44
Susceptible (S)	17	16
Highly susceptible (HS)	43	79

Table 8: Rust score and rust reaction of Cross 1 (DSb 23 × MACS 1575) genotypes in F4 generation of soybean.

Genotype	Rust score	Rust reaction
129-12	3	MR
172-5	7	S
74-8	5	MS
249-8	3	MR
178-2	3	MR
176-1	3	MR
9-4.	3	MR
133-10	5	MS
202-1	5	MS
7-1.	3	MR
74-3	5	MS
64-2	5	MS
172-1	3	MR
38-2	3	MR
9-2.	3	MR
8-12.	3	MR
8-7.	3	MR
224-1	3	MR
249-11	5	MS
14-6.	3	MR
74-10	5	MS
86-1	3	MR

MR- Moderately resistant, MS- Moderately susceptible, HS- Highly susceptible, S- Susceptible.

Table 9: Rust score, percent disease index and rust reaction of cross 2 (DSb 23 × MACS 1460) genotypes in F_4 generation of soybean.

Genotype	Rust score	Rust reaction
479-1	3	MR
58-8	3	MR
217-7	5	MS
23-15	3	MR
129-4	7	S
58-1	3	MR
439-4	3	MR
205-4	5	MS
92-6	3	MR
92-1	3	MR
72-1	5	MS
21-7.	3	MR
60-2	5	MS
377-10	3	MR

MR- Moderately resistant, MS- Moderately susceptible, HS- Highly susceptible, S- Susceptible.

In cross 2, nine genotypes (479-1, 58-8, 23-15, 58-1, 439-4, 92-1, 21-7, 377-10 and 92-6) out of fourteen genotypes screened exhibited moderately resistant reaction and four genotypes recorded (60-2, 72-1, 205-4, 129-4 and 217-7) moderately susceptible reaction to rust disease as quoted in Table 9.

CONCLUSION

The investigation from crossing the contrasting parents to F_5 generation was carried out to identify lines or genotypes which are early flowering with high yield attributing traits coupled with resistant to rust disease. Variability study revealed highly significant variation among the genotypes in both the crosses for all the characters studied. Considerable range of variation was observed for all the yield traits under study indicating enough scope for bringing about improvement in the desired direction. High heritability coupled with high genetic advance were observed for productive pods per plant, pod yield per plant or per plot, plant height and 100 seed weight in both the crosses. Hence, we can rely upon these characters for selection of promising lines. The superior genotypes identified in F_5 generation based on days to maturity, rust resistance and pod yield can be evaluated in multilocation trial to assess their stability performance before releasing as elite genotype and can also be further used as parents in breeding programme for developing early maturing, high yielding and rust resistant genotypes.

Conflict of interest

The authors say that there is no conflict of interest.

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