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Soybean (*Glycine max* L) genotypes performance for quantitative traits during kharif season

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ABSTRACT

This study aimed to evaluate the genetic diversity, growth patterns, yield potential and quality of 40 different soybean genotypes. The experiment was conducted over two years, focusing on a range of key traits. The results confirmed significant genetic variation across all measured characteristics. A key finding was that while environmental factors influenced the traits, several, including the number of pods per plant, plant height and branching, showed high heritability and genetic advance. This means these traits can be effectively improved through direct selection in a breeding programme. The study identified several top-performing genotypes, such as RSC-1172 and AUKS-212, which excelled in yield and related traits. It also found significant variation in protein (37.17 to 52.80%) and oil content (13.42 to 18.89%), allowing breeders to develop varieties for specific market needs. Overall, this research provides valuable genetic information to help breeders create new soybean varieties that are higher-yielding, better adapted to various climates and more tailored for specific commercial purposes.

Keywords: Soybean; genetic variation; heritability; genetic advance; GCV; PCV; direct selection; heterosis breeding

INTRODUCTION

Soybean (*Glycine max* L) is the self-pollinated crop belonging to Leguminosae family having chromosome number 2n = 40 (Nag and Sarawgi 2021). The origins of soybeans can be traced back to the early stages of Chinese agriculture (Dupare et al 2008).

In India, soybeans are primarily used as a source of oil. Only a small portion is used for direct food consumption (10-15%) or as seeds (about 10%) (Talukdar and Shivakumar 2016). It is also known as Golden Bean or Miracle Bean (Sureshrao et al 2014). Soybean contains high quality protein (40%) and oil (20%) (Karr-Lilienthal et al 2005). The enzyme lipoxygenase, found in soybean seeds, is responsible for the unpleasant aroma (Iassonova et al 2008). Production of soybean in India is dominated by Maharashtra and Madhya Pradesh which contribute 89 per cent of the total production. Rajasthan, Andhra Pradesh, Karnataka, Chhattisgarh and Gujarat contribute the remaining 11 per cent production (Kumar et al 2018). India ranked fourth in area with 13.08 million hectares accounting for 9.55 per cent of the world area and fifth in production with 14.98 million tonnes in 2023. In India, area under soyabean during 2025-26 was 79.04 lakh hectares. Among the states, Maharashtra stood first with 37.01 lakh ha followed by Madhya Pradesh (29.74 lakh ha) (Anon 2025).

Soybean is mainly used for soybean meal and soybean oil. It contains different compounds like linolenic acid, isoflavons, lecithins, lectins, linoleic acid, peptides, phytosterols, protein and saponin which help to improve cancer and heart health and regulates lipid metabolism (Dixit et al 2011).

The primary bioactive components of soybeans are phytosterols, isoflavones, proteins or peptides, saponins, carotenoids, tocopherols and protease inhibitors, according to Chatterjee et al (2018) and Wu et al (2017).

Grain yield of soybean is a complex trait influenced by multiple contributing factors. Analyzing both effects exerted directly and indirectly by yield-related components forms the foundation of an effective breeding strategy, ultimately improving yield performance.

Therefore, priority should be given to partition the observed variability into genetic and environmental components, which can be assessed through heritability, genetic advance and coefficients reflecting genotypic (GCV) and phenotypic (PCV) variation.

Therefore, a study was undertaken to evaluate soybean genotypes with respect to yield and its contributing traits under kharif season at Zonal Agricultural Research Station, Ganeshkhind, Pune, Maharashtra.

MATERIAL and METHODS

The experiment on soybean genotypes performance for quantitative traits was conducted during kharif season in randomized block design with three replications at Zonal Agricultural Research Station, Ganeshkhind, Pune, Maharashtra during kharif season 2024.

The land was well prepared with all the agronomical practices with 45 cm × 5 cm spacing. Total forty genotypes of soybean were evaluated for twelve characters viz days to 50 per cent flowering, days to maturity, plant height, plant spread, primary branches per plant, secondary branches per plant, number of seeds per pod, number of pods per plant, oil content, protein content and seed yield per plant.

The data were taken from five randomly selected plants per replication in each plot. Mean sum of square for individual environment and testing the genotype difference were calculated as suggested by Panse and Sukhatme (1985).

RESULTS and DISCUSSION

Table 1 presents the results of an analysis of variance (ANOVA) for 12 different traits in soybean genotypes. The observed differences in these traits among the various genotypes were due to real genetic differences or just random chance.

The data in Table 2 offer valuable insights into the growth, branching patterns and yield and quality traits of 40 different soybean genotypes.

Growth and branching traits

Days to 50 per cent flowering and days to maturity: Days to 50 per cent flowering and days to maturity are fundamental traits for determining a genotype's adaptability to a specific climate and cropping system.

Table 1. Analysis of variance for twelve characters in soybean genotypes

Character	Mean sum of square		
	Replications (2)	Treatments (39)	Error (78)
Days to 50% flowering	4.13	13.06**	2.82
Days to maturity	0.63	46.24**	2.87
Plant height (cm)	10.30	480.52**	17.14
Plant spread (cm)	0.83	138.03**	5.84
Number of primary branches/plant	0.01	1.56**	0.06
Number of secondary branches/plant	0.01	2.30**	0.14
Number of pods/plant	0.34	2608.83**	42.53
Number of seeds/plant	0.01	0.06*	0.03
100-seed weight (g)	4.39	14.10**	1.47
Protein content (%)	10.28	53.31**	4.64
Oil content (%)	0.38	4.98**	0.74
Seed yield/plant (g)	15.61	201.26**	17.13

*Significant at 5% LoS, **Significant at 1% LoS, Values in parentheses indicate degrees of freedom

Table 2. Mean performance of forty soybean genotypes evaluated for growth and yield characteristics

Genotype	Days to 50% flowering	Days to maturity	Plant height (cm)	Plant spread (cm)	Number of primary branches/plant	Number of secondary branches/plant
Monetta	44.33	95.67	56.60	22.00	2.67	5.93
MACS-13	48.67	104.00	77.73	44.60	3.47	6.13
MACS-57	48.33	100.33	87.87	42.40	3.47	5.60
MACS-124	50.33	103.67	93.47	55.00	4.87	7.13
MACS-450	49.67	105.67	86.53	48.53	4.53	6.27
MACS-1037	44.00	100.00	88.40	38.40	4.47	5.80
MACS-1188	46.67	107.00	88.53	49.93	4.80	6.20
MACS-1259	47.67	100.67	80.53	42.13	3.13	6.27
MACS-1281	48.67	100.33	86.20	45.47	4.20	6.53
MACS-1407	47.67	102.33	90.47	45.93	3.60	5.80
MACS-1340	48.00	100.00	82.53	47.20	4.00	5.87
JS-335	48.67	102.67	80.80	40.13	3.67	4.60
JS-71-05	50.67	101.67	87.07	43.13	3.60	5.73
JS-72-44	51.33	109.33	100.73	52.80	5.00	6.40
JS-72-280	50.33	102.33	58.80	29.13	3.00	5.00
JS-72-246	49.33	108.33	102.47	43.13	3.47	5.07
JS-80-21	49.33	100.67	94.60	45.67	4.27	5.33
JS-93-05	43.67	98.67	75.40	33.00	4.20	5.00
JS-97-52	47.33	109.33	86.07	44.93	4.27	5.73
JS-SH-93-01	48.67	102.67	108.47	61.00	4.53	7.80
JS-SH-93-37	49.00	103.00	88.67	40.80	3.73	5.27
NRC-1	49.00	110.33	99.33	50.33	3.47	6.53
NRC-12	53.00	107.33	89.73	46.80	4.47	5.47
NRC-37	47.00	100.67	86.67	41.07	4.13	5.33
NRC-25	46.33	101.00	70.00	35.20	2.73	5.13
PK-416	48.67	110.00	80.20	44.47	4.13	7.13
AS-55	47.33	100.67	72.33	38.13	2.47	3.20
AUKS-212	53.00	110.33	74.67	47.27	4.73	7.07
DS-1529	51.00	108.00	72.80	41.67	4.00	5.00
DS-228	51.00	109.00	66.53	43.07	3.93	5.73
JS-2425	49.00	108.67	58.73	34.87	1.67	4.80
NRC-257	50.00	103.67	72.40	38.73	3.60	5.07
NRC-259	49.67	102.00	73.47	39.20	2.80	4.67
KDS-992	50.00	101.67	81.87	41.27	3.60	5.13
KDS-344	48.67	108.67	75.87	41.87	4.20	6.33
RSC-1172	50.67	110.00	77.27	48.53	3.40	6.40
KDS-753	49.67	105.33	67.60	39.80	3.20	4.47
KDS-726	49.67	103.67	75.60	40.87	3.40	4.73
DS-1510	47.67	103.67	67.20	40.00	2.93	6.27
MDS-5001	51.67	98.67	54.00	41.00	3.73	6.00
Mean	48.88	104.04	80.46	42.74	3.74	5.70
CV	3.44	1.63	5.15	5.66	6.79	6.66
SE (%)	0.97	0.98	2.39	1.40	0.15	0.22
$CD_{0.05}$	2.73	2.76	6.73	3.93	0.41	0.62
$CD_{0.01}$	3.62	3.65	8.93	5.21	0.55	0.82

Table 2. Contd…..

Genotype	Number of pods/plant	Number of seeds/plant	100-seed weight (g)	Protein content (%)	Oil content (%)	Seed yield/plant (g)
Monetta	60.47	2.33	14.91	43.33	16.68	20.46
MACS-13	78.40	2.60	16.50	43.45	15.36	31.79
MACS-57	80.39	2.60	13.51	45.39	18.07	27.40
MACS-124	86.00	3.00	17.28	47.46	15.78	43.36
MACS-450	102.13	2.67	16.53	41.21	17.15	43.45
MACS-1037	83.20	2.53	15.99	40.75	17.30	31.88
MACS-1188	76.31	2.67	15.68	46.62	17.53	30.20
MACS-1259	75.25	2.47	13.01	47.41	15.21	23.48
MACS-1281	77.53	2.47	16.28	43.30	15.38	30.20
MACS-1407	113.25	2.60	13.43	42.39	17.64	37.57
MACS-1340	88.16	2.67	17.24	41.75	16.92	38.62
JS-335	62.53	2.60	12.64	44.28	17.74	19.53
JS-71-05	84.91	2.87	13.14	47.57	16.84	30.49
JS-72-44	116.86	2.53	15.63	39.33	16.85	43.45
JS-72-280	57.14	2.47	12.17	48.95	17.33	16.26
JS-72-246	59.08	2.53	16.33	41.73	17.82	23.39
JS-80-21	111.16	2.33	13.46	46.85	17.35	33.14
JS-93-05	69.55	2.40	15.33	45.76	16.58	24.46
JS-97-52	116.60	2.60	11.65	43.89	18.74	33.74
JS-SH-93-01	160.81	2.53	9.97	48.06	18.89	38.97
JS-SH-93-37	53.49	2.67	16.62	45.08	17.99	22.39
NRC-1	86.61	2.67	14.89	42.62	17.77	32.62
NRC-12	115.66	2.47	12.31	44.52	18.06	33.72
NRC-37	92.29	2.67	12.80	41.35	16.90	30.26
NRC-25	56.96	2.47	16.23	44.00	16.31	21.63
PK-416	76.73	2.40	15.19	46.57	17.10	26.51
AS-55	53.40	2.40	18.54	39.74	16.03	22.75
AUKS-212	156.07	2.73	11.67	41.56	13.42	47.54
DS-1529	76.21	2.47	13.52	47.07	16.95	24.20
DS-228	97.95	2.73	15.03	42.79	16.98	38.35
JS-2425	61.67	2.73	15.50	50.81	17.17	24.83
NRC-257	94.90	2.67	13.00	40.63	14.36	31.26
NRC-259	77.03	2.73	12.11	48.64	16.72	24.32
KDS-992	82.15	2.87	16.49	37.93	14.74	37.36
KDS-344	144.46	2.80	11.39	52.05	15.62	43.77
RSC-1172	167.36	2.60	11.61	37.13	14.25	47.94
KDS-753	93.78	2.67	15.42	32.39	14.35	36.28
KDS-726	87.02	2.47	18.63	39.83	16.32	37.95
DS-1510	122.06	2.67	11.07	52.82	18.52	34.08
MDS-5001	57.00	2.73	15.55	38.35	16.73	23.06
Mean	90.31	2.60	14.46	43.88	16.69	31.57
CV	7.22	7.61	8.41	4.91	5.18	13.11
SE (%)	3.77	0.11	0.70	1.24	0.50	2.39
$CD_{0.05}$	10.60	0.32	1.98	3.50	1.41	6.73
$CD_{0.01}$	14.06	0.43	2.62	4.65	1.86	8.92

For days to 50 per cent flowering, the genotypes ranged from a low of 43.67 days to a high of 53.00 days. Similarly, for days to maturity, the range was from 95.67 to 110.33 days. This wide range is a huge advantage for breeders. They can select early-maturing genotypes for regions with a shorter monsoon season or for double-cropping systems. In contrast, later-maturing genotypes could be chosen for areas with a longer, more favourable growing season to maximize yield potential.

Zheng et al (2023) reported some soybean varieties exhibiting a longer growth period displaying overall better performance.

Plant height and plant spread: Plant height and spread are key components of plant architecture, influencing light interception, photosynthesis and susceptibility to lodging (falling over). There was a notable difference in these traits among the genotypes. The plant height ranged from 54.00 to 108.47 cm. Tallest genotypes were JS-SH-93-01 (108.47 cm), JS-72-246 (102.47 cm) and JS-72-44 (100.73 cm), the three being at par. Shortest plants were recorded in MDS-5001 (54.00 cm), Monetta (56.60 cm), JS-2425 (58.73 cm) and JS-72-280 (58.80 cm), which were at par. JS-SH-93-01 also had the widest spread at 61.00 cm, whereas, Monetta had the narrowest at 22.00 cm. Conversely, for traditional, wider-row planting, a taller, more robust plant like JS-SH-93-01 could be a better option.

The reason behind this might be adequate rainfall, temperature, light, humidity etc. Kumawat et al (2023) reported high variability for plant height among soybean genotypes. Wide plant spread is often linked to better photosynthetic efficiency (Singh 2022). For high-density planting, a shorter, more compact plant like MDS-5001 might be preferable to prevent overcrowding and shading.

Number of primary and secondary branches per plant: Branching is directly linked to the number of pods a plant can produce, making it a critical component of yield.

The data reveal that some genotypes were much more branched than others. The number of primary branches ranged from a low of 1.67 to a high of 5.00. Similarly, the range for secondary branches was from 3.20 to 7.80. More branches typically mean more nodes and, therefore, more sites for pod development, which directly correlates with higher seed yield. Genotypes like JS-SH-93-01, MACS-124 and AUK-212 with a high number of both primary and secondary branches, were excellent candidates for a breeding programme aimed at increasing yield. Gawale et al (2023) reported that the number of branches per plant ranged from 3.64 to 5.56 among soybean genotypes. Genotype G2 (5.56) had significantly higher number of nodes per plant over remaining genotypes except G7 (5.17) which was at par. However, genotype G3 (3.64) noted minimum number of branches per plant.

Yield and quality traits

Number of pods and seeds per plant: The number of pods a plant produces is a primary driver of its total yield. The mean number of pods was 90.31, but the genotypes showed a huge range from 53.49 to 167.36 pods per plant. RSC-1172, JS-SH-93-01 and AUKS-212 were the star performers with an incredible 167.36, 160.81 and 156.07 pods, which were at par. This highlights the enormous potential for genetic improvement.

The mean number of seeds per plant was 2.60. While this trait showed less overall variation compared to pods, there were still significant differences. The highest number of seeds per pod was 3.00 and lowest was 2.33. This trait contributes directly to the overall yield, but the number of pods seemed to be a more influential factor. Bhuva et al (2020) also reported highly significant and positive correlation of seed yield per plant with number of pods per plant.

Seed weight and yield per plant: Seed weight and yield per plant are the most critical traits for a farmer. They directly measure the productivity of a genotype. The average 100-seed weight was 14.46 g. The 100-seed weight ranged from lowest 9.97 g to heaviest 18.63 g.

Seed weight is a key component of yield, so heavy-seeded genotypes are valuable parents for breeding programmes. The mean seed yield per plant was 31.57 g. The top-yielding genotypes were RSC-1172 (47.94 g), AUKS-212 (47.54 g), KDS-344 (43.77 g), MACS-450 (43.45 g), JS-72-44 (43.45 g) and MACS-124 (43.36 g), all being at par. Interestingly, the top-yielding genotypes, RSC-1172 and AUKS-212 were also among high number of pods, demonstrating the strong relationship between these two traits. This

Table 3. Estimation of genetic parameters for 12 different characters in various soybean genotypes

Character	Range	Mean	GCV (%)	PCV (%)	Heritability (h^2) (bs) (%)	Genetic advance (GA) (at 5% K)	GA as per cent of mean (at 5% K)
Days to 50% flowering	43.67-53.00	48.88	3.78	5.11	54.70	2.82	5.76
Days to maturity	95.67-110.33	104.04	3.65	4.00	83.42	7.15	6.87
Plant height (cm)	54.00-108.47	80.46	15.45	16.28	90.01	24.29	30.19
Plant spread (cm)	22.00-61.00	42.74	15.53	16.53	88.29	12.85	30.06
Number of primary branches/plant	1.67-4.87	3.74	18.94	20.12	88.63	1.37	36.74
Number of secondary branches/plant	4.47-7.80	5.70	14.90	16.32	83.36	1.60	28.02
Number of pods/plant	53.49-167.36	90.31	32.38	33.18	95.26	58.81	65.11
Number of seeds/pod	2.33-3.00	2.60	3.72	8.47	19.27	0.09	3.36
100-seed weight (g)	9.97-18.54	14.46	14.19	16.50	74.02	3.64	25.16
Protein content (%)	32.39-52.87	43.88	9.18	10.41	77.75	7.32	16.67
Oil content (%)	13.47-18.88	16.69	7.13	8.81	65.42	1.98	11.87
Seed yield/plant (g)	16.26-47.94	31.57	24.82	28.07	78.17	14.27	45.20

GCV: Genotypic coefficients of variation, PCV: Phenotypic coefficients of variation

data clearly show that selecting for more pods is an effective way to boost overall yield.

Protein and oil content: Soybean is a dual-purpose crop, grown for both its protein-rich meal and oil. The average protein content was 43.88 per cent. The protein level ranged from 37.13 to 52.82 per cent. This variation allows breeders to specifically target the protein market.

The average oil content was 16.69 per cent. Oil content ranged from highest 18.89 per cent to lowest 13.42 per cent. This variation is essential for developing varieties for the edible oil industry.

The analysis of soybean genotypes revealed significant genetic diversity, which is a major advantage for breeding programmes. The study identified key performers for different traits: some genotypes matured early, ideal for short growing seasons, while others were late-maturing and high-yielding.

The data also highlighted genotypes with superior plant architecture for different farming systems as well as those with high pod counts and heavy seeds, which were directly linked to high overall yield. Most importantly, the study found specific genotypes rich in either protein or oil, allowing breeders to develop new varieties tailored for a variety of market needs, from food to industrial oil production.

Yield can be improved by selecting superior genotypes directly related to seed yield and utilizing these genotypes in breeding programmes to enhance grain yield (Jain et al 2023).

Genetic parameters

Based on the genetic analysis of various soybean traits, Table 3 provides crucial insights for breeders aiming to develop improved varieties. A key finding was that for all characters, the PCV was greater than the GCV. This consistently indicates that environmental factors played a role in the observed variability of these traits. Similar findings have been reported by other researchers, including Ekka and Lal (2016), Guleria et al (2019), Dutta and Goswami (2023) and Khumukcham et al (2022).

Several traits were identified as being highly heritable with significant potential for genetic improvement through direct selection. For instance, the number of pods per plant demonstrated exceptionally high heritability (95.26%) and a very high genetic advance (65.11%). This strong combination suggests that breeders can be highly effective in increasing this trait in future generations simply by selecting plants with more pods.

Similarly, plant height and plant spread also showed high heritability (90.01 and 88.29%

respectively) coupled with substantial genetic advance (30.19 and 30.06% respectively). This means that selecting for taller plants or a wider plant spread would likely lead to significant genetic gains. The number of primary and secondary branches per plant was also found to be highly heritable (88.63 and 83.36% respectively) and showed good potential for improvement (36.74 and 28.02% respectively).

Traits with high heritability that were coupled with a low genetic advance, such as plant spread, days to maturity, 100-seed weight, protein content, seed yield per plant and oil content, suggest that these characteristics are controlled by non-additive gene action, specifically dominance and epistasis. In such cases, simple selection is not an effective strategy for crop improvement. Therefore, heterosis breeding, also known as hybrid breeding, would be a more appropriate method to improve these traits.

Other traits showed a more complex genetic architecture. Seed yield per plant had a high genetic advance (45.20%) and reasonably high heritability (78.17%), suggesting that it could be improved through selection, though perhaps not as easily as traits like pod number. The PCV (28.07%) being significantly higher than the GCV (24.82%) hints at a notable environmental influence on yield. Similarly, protein content (77.75%) and 100-seed weight (74.02%) had high heritability and good potential for genetic advance, making them suitable targets for selection.

In contrast, the number of seeds per pod had a very low heritability (19.27%) and a low genetic advance (3.36%). The significant difference between its PCV (8.47%) and GCV (3.72%) indicates that environmental factors had a strong influence, making direct selection for this trait largely ineffective. The traits oil content (65.42%), days to 50 per cent flowering (54.70%) and days to maturity (83.42%) had moderate to high heritability but relatively low genetic advance, suggesting that while they are genetically controlled, the potential for rapid improvement through simple selection is limited.

This study calculated broad-sense heritability, which accounts for both additive and non-additive gene effects (Hanson et al 1956). Heritability is a crucial metric for estimating the heritable differences in genotypes and is essential for identifying which traits can be effectively improved through breeding based on their phenotypic performance.

The findings of this study are in line with other research. Patil et al (2011) and Reni and Rao (2013) observed similar high heritability for traits like plant height, seed yield per plant and number of pods per plant. Baraskar et al (2014) also reported comparable findings for plant height, primary branches, oil content and seed yield. Kuswantoro et al (2021) and Mahbub and Shirazy (2016) also recorded high heritability with high genetic advance for several traits, including number of branches and plant height. These results are further supported by Kumar et al (2020) and Bairagi et al (2024).

This research successfully identified a wide range of genetic diversity within the soybean genotypes, providing breeders with a clear roadmap for developing new, improved varieties. The study showed that traits like pod count, plant height and branching are highly heritable and can be significantly improved through simple selection. It also pinpointed top-performing genotypes that are ideal for specific climates and market needs, whether that's for high yield, heavy seeds or superior protein and oil content. The findings are a huge deal for farmers, as they lay the groundwork for creating a new generation of soybeans that are better adapted to various conditions and more productive.

CONCLUSION

This research provides a treasure trove of genetic information for soybean breeders, confirming that there is a wealth of diversity to work with. The study's most important finding is that traits directly linked to yield and plant architecture, such as the number of pods per plant, plant height and branching, are highly heritable. This is great news because it means breeders can confidently select plants with these desirable traits and expect to see significant improvements in future generations.The data also identified specific, high-performing genotypes that can be used as parent lines in future breeding programmes.

For example, genotypes like RSC-1172 and AUKS-212 were star performers, excelling in traits like pod count and overall yield. The wide range in maturity times also gives breeders a huge advantage, allowing them to develop varieties perfectly suited for different cropping systems and climates. Beyond yield, the study highlighted the potential to improve a soybean's quality. The significant variation in protein and oil content means that breeders can develop new varieties specifically for the high-protein food market or the edible oil industry. While some traits, such as seeds per pod, were found to be heavily influenced by the environment, the study's overall message is clear: the genetic resources are there. The findings provide a solid, scientific roadmap for creating a new generation of superior soybean varieties that are more productive, resilient and tailored to meet both farmer and market demands.

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