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RESEARCH PAPER

Impact of seasons on genetic variability parameters in soybean (*Glycine max* (L.) Merrill)

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Abstract: Soybean being a photoperiod sensitive crop usually grown during *kharif* season. Due to higher returns from soybean, the farmers are growing even in *rabi* and summer seasons. Hence, understanding genetic variability during different seasons is essential for undertaking selection during particular season. In this regard, fifteen soybean genotypes were studied at Main Agriculture Research Station, UAS, Dharwad during *kharif*, *rabi* and summer. Significant differences were observed among the genotypes for physiological, phenological, yield components, yield and quality traits in all the seasons. Higher mean was noted across soybean genotypes for chlorophyll 'a', days to maturity, plant height, protein content, number of branches per plant, number of pods per plant, hundred seed weight and seed yield during *kharif* while for oil content during *rabi*. Higher range was observed for SCMR, chlorophyll 'a', 'b' and total, days to initiation of flowering, days to 50 per cent flowering, plant height, number of branches per plant during summer. PCV and GCV was high for chlorophyll 'b', number of pods per plant, seed yield during *rabi* and summer. Chlorophyll 'b', plant height, number of pods per plant and seed yield have high heritability and GAM in all the seasons indicating the scope for phenotypic selection.

Key words: Genetic variability, Heritability, Seasons, Selection, Soybean

Introduction

Soybean (*Glycine max* (L.) Merrill), given its numerous and diverse applications, is an important legume crop on a worldwide scale which exhibits a unique amalgamation of properties inherent to both legumes and oilseeds. It has higher protein (30 – 45%) and oil content (15 – 24%) along with numerous applications namely, soy milk, soy meat, tofu, margarine, pharmaceuticals, cosmetics, biodiesel (Smith 1981; Fehr *et al.,* 1992; Rao *et al.,* 2002). Additionally, soybean is renowned for its ability to enrich soil nitrogen through biological nitrogen fixation, suppresses weed and suits mixed as well as sequential cropping system. Because of its multiple uses soybean is entitled as 'wonder bean', 'miracle bean' and 'golden bean'.

The fundamental necessity for crop improvement lies in genetic variability in the studied material as it offers scope for selection. Therefore, the success of selection depends on the extent, nature, and magnitude of genetic variability especially the heritable portion present among the material (Dubey *et al.,* 2015). It is essential to dissect the observed variability into heritable and non-heritable components, which are further explained as genotypic and phenotypic coefficients of variation (GCV and PCV), heritability, and genetic advance (Athoni and Basavaraja, 2012). The traits in soybean are primarily influenced by genetic makeup of the genotypes and the environmental conditions in which they grow, including the interactions between different genotypes and environments (Ajay *et al.,* 2014). Soybean being a photoperiod sensitive crop is mainly grown during *kharif* season in India. But due to increased demand for soybean, the crop is being grown during *rabi* and summer seasons also. Minimal efforts have been made to understand genetic variability in *rabi* (Praveen *et al.,* 2005; Pallavi *et al.,* 2016) and summer (Yamgar *et al.,* 2021; Chawan *et al.,* 2023) seasons which are characterized by different photoperiod and temperature. Few studies have been carried out to know the genetic variability among a set of soybean genotypes in all the three seasons (Deshmukh *et al.,* 2019). Hence, the current investigation was carried out to understand the genetic variability among the elite soybean genotypes during *kharif*, *rabi* and summer.

Material and methods

Fifteen elite soybean genotypes were sown during *kharif* 2022, *rabi* 2022-23 and summer 2023 by following Randomized Complete Block Design with three replications. The details of these genotypes is presented in Table 1. The data on weather parameters recorded at meteorological observatory, Main Agriculture Research Station, University of Agricultural Sciences, Dharwad and the data of day length that was obtained from the website Goddard Institute of Space Studies, NASA for *kharif* 2022, *rabi* 2022-23 and summer 2023 seasons during the cropping period is provided in Table 2.

The recommended doses of fertilizers of 40 Kg N, 80 Kg P_2O_5 and 25 Kg K_2O per hectare was applied in the form of urea, DAP and MOP as basal dose. The seeds were treated with rhizobium biofertilizer and Carboxin + Thiram (Vitavax @ 3 g/kg seeds) before sowing. Two seeds per hill of each genotype were hand dibbled in four rows having a length of 4 m with row to row spacing of 30 cm and plant to plant spacing of 10 cm accounting for plot size of 4 m × 1.2 m. The seeds were sown on 17th June, 2022, 29th October 2022 and 11th January 2023 during *kharif*, *rabi* and summer season, respectively. Irrigations were provided at 15 days interval during *rabi* and summer. All the recommended agronomic and plant protection practices were

Table 1. List of soybean genotypes with pedigree, salient features

Genotype	Pedigree	Special features
MACS 330	Monetta × EC 95937	Photo period insensitive
Local Black Soybean	Indigenous native variety of Dharwad and Belgavi districts of Karnataka	Seed viability more than 12 months and >42% protein
JS 335	JS-78-77 × JS-71-05	Widely adapted
JS 93-05	Selection from PS 73-22	Early maturing
DSb 21	JS 335 × EC 241778	Rust resistant
DSb 23	JS 335 × EC 241780	
DSb 28	JS 93-05 × EC 241780	
DSb 33	DSb 21 × JS 95-60	
DSb 39	JS 335 × EC 242104	
DSb 34	DSb 23 × JS 95-60	Early maturing and rust resistant
DSb 40	EC 241780 × JS 95-60	
DLSb 1	SL 979 × DSb 21	Rust and Y M V tolerant
DLSb 3	(DSb 23 × SL 958) × DSb 23	
DLSb 5	DSb 28 × SL 958	
DLSb 6	DSb 23 × SL 958	

followed to raise a good crop. Observations were recorded for physiological traits at 45 days after sowing (DAS) (SPAD Chlorophyll Meter Reading - ìmol/m², chlorophyll 'a', 'b' and total - mg/g, phenological traits (days to initiation of flowering, days to 50 per cent flowering and days to maturity), yield components (plant height - cm, number of branches per plant, number of pods per plant, number of seeds per pod, hundred seed weight - g), seed yield (kg/ha) and quality traits (seed protein content (%) and seed oil content - %) in all the three seasons.

Nitrogen content in each soybean genotype, replication wise, was estimated by Kjeldhal method (Kjeldhal, 1883) using Kelplus nitrogen estimation system for digestion (Kelvac VA) and distillation (Elite EX VA). Later protein content in seed was calculated by multiplying the nitrogen content with a factor 6.25. Known quantity (25 g) of clean seed samples of each soybean genotype was used from each replication and oil content was estimated by using Nuclear Magnetic Resonance (NMR) (MCQ+) instrument at UAS, Raichur. The data recorded on various traits during field experiment was statistically analysed following the analysis of variance for Randomized Complete Block Design on the basis of the model proposed by Cochran and Cox (1957) using the "variability" package in the R Studio software (4.3.1).

Results and discussion

Analysis of variance indicated significant variability among genotypes for physiological traits at 45 DAS (SPAD Chlorophyll Meter Reading, chlorophyll 'a', 'b' and total, phenological traits (days to initiation of flowering, days to 50 per cent flowering and days to maturity), yield components (plant height, number of branches per plant, number of pods per plant, number of seeds per pod, hundred seed weight), seed yield and quality traits (seed protein content and seed oil content) during *kharif* 2022, *rabi* 2022-23 and summer 2023 (Table 3, 4 and 5). This signifies the existence of genetic variability among genotypes during different seasons and hence there is scope for selection in different seasons. Earlier, Ibrahim (2012), Saicharan *et al.* (2022) during *kharif*, Pallavi *et al.* (2016) during *rabi*, Mandic *et al.* (2020) during summer, Deshmukh *et al.* (2019) during all the three seasons reported significant differences among soybean genotypes for different traits under different seasons.

Higher variability in terms of range was observed among soybean genotypes for SCMR (32.50-46.10 ìmol/m²), chlorophyll 'a' (1.42-2.00 mg/g), plant height (22.20-85.40 cm), number of branches per plant (2-6) during summer over *kharif* and *rabi* (Table 6). This implies more differential response of soybean genotypes under study for these traits which could be attributed to prevailing photoperiod (11 h 56 min, Table 2) and higher temperature (33.8^{O}C, Table 2) during summer (Yamgar *et al.*,

Table 2. Photo period and meteorological data observed during *kharif* 2022, *rabi* 2022-23 and summer 2023

Season	Month	Photo period Range (in hours)		Temperature (^{O}C) Maximum	Minimum	Relative humidity(%) Maximum	Minimum	Rainfall (mm)	No. of rainy days
Kharif 2022	June	13:02 (17th July)	11:47 (2nd October)	29.9	21.0	85.7	76.5	102.8	7
	July			26.6	20.5	91.7	82.5	186.4	14
	August			27.4	20.3	90.7	82.4	113.2	14
	September			28.7	20.0	89.8	74.2	195.6	11
	October			28.9	18.6	85.6	67.8	208.6	8
Mean/Total			12:33	28.3	20.1	88.7	76.7	806.6	54
Rabi 2022-23	October	11:36 (29thOctober)	11:15 (7thFebruary)	28.9	18.6	85.6	67.8	208.6	8
	November			29.6	16.5	72.8	45.6	2.8	1
	December			29.6	15.6	76.6	44.2	3.2	1
	January			30.0	13.8	70.4	33.6	0	0
	February			32.6	15.2	63.5	28.1	0	0
Mean/Total			11:20	30.1	15.9	73.8	43.9	214.6	10
Summer 2023	January	11:16 (11th January)	12:42 (2nd May)	30.0	13.8	70.4	33.6	0	0
	February			32.6	15.2	63.5	28.1	0	0
	March			34.1	17.4	67.0	40.5	0	0
	April			36.4	18.1	73.6	53.9	26.4	3
	May			35.7	19.3	74.6	44.4	62.6	7
Mean/Total			11:56	33.8	16.8	69.8	40.0	89.0	10

Table 3. Mean sum of squares of different traits in soybean for *kharif* 2022

Source of Variation	df	SPAD chlorophyll meter reading	Chlorophyll 'a'	Chlorophyll 'b'	Total chlorophyll	Days to initiation of flowering	Days to 50 per cent flowering	Days to maturity	Plant height
Replication	2	1.48	0.0001	0.0006	0.002	0.29	0.02	0.47	1.67
Genotypes	14	19.52**	0.04**	0.04**	0.06**	40.13**	41.42**	238.32**	310.11**
Error	28	1.31	0.0004	0.0004	0.001	0.29	0.24	0.35	2.29
Total	44	22.31	0.0405	0.041	0.063	40.71	41.68	239.14	314.07

Source of Variation	df	Number of branches per plant	Number of pods per plant	Number of seeds per pod	Hundred seed weight	Seed yield	Protein content	Oil content
Replication	2	0.07	1.76	0.02	0.02	45388	0.02	0.03
Genotypes	14	0.77**	202.85**	0.52**	2.35**	1439413**	3.58**	12.08**
Error	28	0.07	2.45	0.02	0.04	112369	0.02	0.15
Total	44	0.91	207.06	0.56	2.41	1597170	3.62	12.26

* and **- Significant at 5% and 1% level of probability, respectively.
df – degrees of freedom

Table 4. Mean sum of squares of different traits in soybean for *rabi* 2022-23

Source of Variation	df	SPAD Chlorophyll meter reading	Chlorophyll 'a'	Chlorophyll 'b'	Total chlorophyll	Days to initiation of flowering	Days to 50 per cent flowering	Days to maturity	Plant height
Replication	2	0.42	0.002	0.002	0.001	0.07	0.09	1.09	0.09
Genotypes	14	13.02**	0.05**	0.03**	0.12**	28.61**	12.88**	99.12**	80.23**
Error	28	0.39	0.001	0.001	0.001	0.30	0.23	0.57	0.54
Total	44	13.83	0.053	0.033	0.122	28.98	13.2	100.78	80.86

Source of Variation	df	Number of branches per plant	Number of pods per plant	Number of seeds per pod	Hundred seed weight	Seed yield	Protein content	Oil content
Replication	2	0.09	0.20	0.02	0.001	9565	0.06	0.07
Genotypes	14	0.88**	122.76**	0.50**	6.84**	988604**	3.63**	9.11**
Error	28	0.09	0.11	0.07	0.023	21029	0.03	0.89
Total	44	1.06	123.07	0.59	6.864	1019198	3.72	10.07

* and **- Significant at 5 % and 1 % level of probability, respectively.
df – degrees of freedom

Table 5. Mean sum of squares of different traits in soybean for summer 2023

Source of Variation	df	SPAD Chlorophyll meter reading	Chlorophyll 'a'	Chlorophyll 'b'	Total chlorophyll	Days to initiation of flowering	Days to 50 per cent flowering	Days to maturity	Plant height
Replication	2	1.60	0.004	0.003	0.01	0.87	1.69	0.03	2.93
Genotypes	14	21.29**	0.04**	0.58**	0.92**	78.57**	76.64**	200.96**	500.16**
Error	28	1.63	0.002	0.004	0.01	1.01	0.98	0.18	3.93
Total	44	24.52	0.046	0.587	0.94	80.45	79.31	201.17	507.02

Source of Variation	df	Number of branches per plant	Number of pods per plant	Number of seeds per pod	Hundred seed weight	Seed yield	Protein content	Oil content
Replication	2	0.02	0.09	0.02	0.02	8131	0.08	0.14
Genotypes	14	1.36**	128.68**	0.41**	2.96**	451890**	4.00**	5.79**
Error	28	0.03	1.87	0.02	0.01	25399	0.06	1.18
Total	44	1.41	130.64	0.45	2.99	485420	4.14	7.11

* and **- Significant at 5 % and 1 % level of probability, respectively.
df – degrees of freedom

Table 6. Mean, range and genetic components of variation for different traits of soybean genotypes during *kharif* 2022, *rabi* 2022-23 and summer 2023

Trait	Season	Mean	Range		Phenotypic co-efficient of variation	Genotypic co-efficient of variation	Heritability (%)	Genetic advance over mean
			Minimum	Maximum				
SPAD Chlorophyll meter reading (imol/m²)	*Kharif*	36.66	30.20	41.20	7.41	6.72	82.20	12.55
	Rabi	37.90	33.60	43.10	5.66	5.41	91.50	10.67
	Summer	37.34	32.50	46.10	7.66	6.86	80.05	12.64
Chlorophyll a' (mg/g)	*Kharif*	2.05	1.87	2.29	5.34	5.25	96.67	10.63
	Rabi	1.49	1.19	1.74	8.93	8.70	94.89	17.46
	Summer	1.66	1.42	2.00	7.57	7.15	89.24	13.92
Chlorophyll 'b' (mg/g)	*Kharif*	0.74	0.50	0.94	14.95	14.70	96.69	29.78
	Rabi	0.45	0.27	0.66	21.96	20.69	88.78	40.15
	Summer	1.19	0.50	1.87	37.23	36.80	97.71	74.93
Total chlorophyll (mg/g)	*Kharif*	2.80	2.56	3.16	5.17	5.05	95.24	10.15
	Rabi	1.94	1.48	2.34	10.47	10.32	97.08	20.95
	Summer	2.85	1.83	3.59	19.55	19.39	98.36	39.61
Days to initiation of flowering	*Kharif*	42.00	31.00	48.00	8.75	8.65	97.87	17.64
	Rabi	41.00	37.00	50.00	7.71	7.59	96.87	15.39
	Summer	44.00	30.00	53.00	11.69	11.47	96.24	23.18
Days to 50 per cent flowering	*Kharif*	44.00	33.00	50.00	8.42	8.35	98.31	17.05
	Rabi	42.00	39.00	51.00	5.07	4.94	94.79	9.90
	Summer	46.00	32.00	55.00	11.05	10.84	96.28	21.92
Days to maturity	*Kharif*	96.00	69.00	107.00	9.28	9.26	99.56	19.03
	Rabi	86.00	70.00	94.00	6.75	6.69	98.31	13.66
	Summer	95.00	69.00	104.00	8.63	8.62	99.73	17.74
Plant height (cm)	*Kharif*	50.73	38.60	79.40	20.19	19.97	97.82	40.68
	Rabi	28.18	18.00	38.00	18.48	18.29	98.00	37.30
	Summer	39.91	22.20	85.40	32.61	32.23	97.68	65.62
Trait	Season	Mean	Range		Phenotypic co-efficient of variation	Genotypic co-efficient of variation	Heritability (%)	Genetic advance over mean
			Minimum	Maximum				
Number of branches per plant	*Kharif*	5.27	4.00	6.00	10.43	9.20	77.88	16.73
	Rabi	3.98	2.00	5.00	14.92	12.90	74.77	22.99
	Summer	4.36	2.00	6.00	15.83	15.28	93.24	30.40
Number of pods per plant	*Kharif*	49.16	24.00	68.00	16.93	16.63	96.47	33.64
	Rabi	29.67	12.00	38.00	21.58	21.55	99.74	44.34
	Summer	26.87	19.00	42.00	24.72	24.19	95.76	48.77
Number of seeds per pod	*Kharif*	3.04	2.00	4.00	14.22	13.35	88.15	25.81
	Rabi	3.02	2.00	4.00	15.26	12.51	67.18	21.12
	Summer	2.89	2.00	4.00	13.51	12.49	85.43	23.78
Hundred seed weight (g)	*Kharif*	13.34	11.50	16.00	6.75	6.58	95.12	13.23
	Rabi	11.82	7.10	13.50	12.82	12.76	99.02	26.15
	Summer	9.50	6.40	10.70	10.51	10.44	98.74	21.37
Seed yield (Kg/ha)	*Kharif*	3565	1350	4609	20.89	18.66	79.74	34.32
	Rabi	1580	338	3157	37.10	35.95	93.88	71.76
	Summer	855	183	2017	47.88	44.10	84.84	83.68
Protein content (%)	*Kharif*	38.67	37.30	41.70	2.84	2.82	98.52	5.76
	Rabi	37.08	35.88	40.00	2.99	2.96	97.58	6.02
	Summer	38.18	36.90	41.16	3.07	3.00	95.62	6.04
Oil Content (%)	*Kharif*	20.42	17.69	22.97	9.94	9.77	96.47	19.76
	Rabi	21.20	17.99	24.70	8.99	7.81	75.38	13.96
	Summer	19.78	17.51	22.83	8.33	6.27	56.63	9.72

2021; Chawan *et al.,* 2023). In contrast to this, maximum variability was observed for seed yield (1350 - 4609 kg/ha) during *kharif* when compared to *rabi* and summer which could be attributed to longer photoperiod in *kharif* (12 h 33 min), which was also noted by Dutta *et al.* (2021) while studying forty soybean genotypes during *kharif* in Assam.

Higher mean was noted across soybean genotypes for chlorophyll 'a' (2.05), days to maturity (96), plant height (50.73 cm), number of branches per plant (5.27), number of pods per plant (49.16), hundred seed weight (13.34 g) seed yield (3565 kg/ha) and protein content (38.67%), during *kharif* compared to *rabi* and summer (Table 6). This suggests that when soybean genotypes were exposed to longer photoperiod (*kharif*), there is an increased manifestation of these traits in majority of the studied genotypes. Under longer photoperiod, the genotypes undergone a greater number of days to reach maturity with an increase in plant height, number of branches per plant, number of pods per plant and hundred seed weight which ultimately resulted in increased seed yield (Junior *et al.,* 2017; Deshmukh *et al.,* 2019; Bateman *et al.,* 2020; El Toum *et al.,* 2020; Mandic *et al.,* 2020; Jarecki and Bobrecka-Jamro, 2021). On the contrary, mean oil content (21.20) was higher during *rabi* due to reduced photoperiod (Junior *et al.,* 2017) and alteration in the chemical characteristics of soybean seeds (Mandic *et al.,* 2020). Similar changes in oil content were reported by Dwivedi *et al.* (2000) in groundnut.

Components of genetic variation

In all the three seasons, PCV was higher than GCV for all the traits, indicating environmental influence on the expression of the studied traits. PCV and GCV was high (> 20%) for chlorophyll 'b', number of pods per plant, seed yield during *rabi* and summer (Table 6). This indicates that the different factors like photoperiod and temperature (Table 2) existing during *rabi* and summer were favorable for expression of these traits in the studied genotypes. Earlier, higher PCV and GCV was reported by Praveen *et al.* (2005), Pallavi *et al.* (2016) during *rabi*, Yamgar *et al.* (2021) during summer for number of pods per plant and seed yield while studying soybean genotypes. In contrast, PCV and GCV was low (0 - 10 %) for SCMR, chlorophyll 'a', days to maturity, protein and oil content in all the seasons (Table 6). This suggests that there is relatively less variation in these traits among the studied genotypes in all the three seasons. Previously, lower PCV and GCV was reported by Chandrawat *et al.* (2017) and Shruthi *et al.* (2021) for days to maturity, Baraskar *et al.* (2014) for protein and oil content during *kharif*, Dubey *et al.* (2015) for days to maturity during *rabi*, Chawan *et al.* (2023) and Yamgar *et al.* (2021) for days to maturity during summer while studying soybean genotypes.

High heritability (>60%) combined with high genetic advance as per cent of mean (GAM, >20%) was noted for chlorophyll 'b', plant height, number of pods per plant, number of seeds per pod and seed yield in all the seasons. High GAM was due to higher variability and lower mean in all the three seasons (Table 6). This suggests that these traits are predominantly governed by additive gene action hence, selection based on phenotype would be effective under different photoperiods. Earlier, high heritability and high GAM was reported in soybean genotypes by Baraskar *et al.* (2014) (plant height, number of pods per plant, seed yield), Shruthi *et al.* (2021) (plant height, number of pods per plant, number of seeds per pod, seed yield) and Bairagi *et al.* (2023) (number of pods per plant, seed yield) during *kharif*, Dubey *et al.* (2015) (number of pods per plant, number of seeds per pod, seed yield) and Pallavi *et al.* (2016) (plant height, seed yield) during *rabi*, and Akram *et al.* (2011) (plant height, number of pods per plant, seed yield) and Yamgar *et al.* (2021) (plant height, number of pods per plant, seed yield) during summer. The traits total chlorophyll, number of branches per plant and hundred seed weight had high heritability with high GAM during *rabi* and summer (Table 6). The high GAM was mainly observed due to the presence of high variability. Similar findings were also documented by Akram *et al.* (2011) during summer, Pallavi *et al.* (2016) and Shruthi *et al.* (2021) during *rabi* for number of branches per plant and hundred seed weight. The change in the heritability among different seasons with same set of genotypes is attributed to environmental conditions (photoperiod/temperature) in the different seasons, as heritability is a characteristic specific to particular population and is subject to environmental influences (Visscher *et al.,* 2008).

High heritability coupled with low (< 10%) or moderate (10 – 20%) GAM was observed among genotypes for SCMR, chlorophyll 'a', days to maturity and protein content in all the seasons (Table 6). Low GAM was observed due to low variability among the studied genotypes in all the three seasons. This suggests that these traits governed by a combination of additive and non-additive gene action and hence selection based on phenotype will not be effective for these traits. Earlier, Baraskar *et al.* (2014) during *kharif*, Chandrawat *et al.* (2017) during *rabi*, Yamgar *et al.* (2021) during summer reported similar results for both days to maturity and protein content while studying different soybean genotypes.

Conclusion

PCV was higher compared to GCV for all the traits in all the three seasons indicating influence of environment on the existing variability. Heritability was high for all the traits, except oil content, during all the three seasons implying higher contribution of additive gene action hence, scope for selection. High GAM for most of the traits indicated effectiveness of phenotypic selection through which high genetic gain could be achieved. Thus, the present study has indicated sufficient variability and scope for selection among the soybean genotypes for physiological, phenological, yield and yield components and quality traits.

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