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Effect of sowing dates and varieties on growth, yield, quality and economics of summer soybean (*Glycine Max* L.) under south Saurashtra conditions of Gujarat

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Abstract

A field experiment was conducted during the summer seasons of 2023 and 2024 at Sagadivdi Farm, Department of Seed Science and Technology, Junagadh Agricultural University, Junagadh, to study the effect of sowing dates and varieties on the growth, yield, quality and economics of summer soybean (*Glycine max* L.). The experiment, comprising three sowing dates (4th week of January, 2nd week of February and 4th week of February) as main-plot treatments and four varieties (GJS-3, GS-4, NRC-138 and Phule Sangam) as sub-plot treatments was laid out in a Split Plot Design with three replications. Sowing in the 2nd week of February produced significantly higher number of pods per plant (37.11, pooled), seed yield (1322 kg/ha) and haulm yield (1876 kg/ha) than the other two dates, whereas the 4th week of January recorded the tallest plants, the highest dry weight per plant at harvest and the highest number of nodules per plant. Among varieties, GS-4 remained statistically at par with GJS-3 for most growth and yield traits and recorded the highest seed yield (1238 kg/ha), while NRC-138 recorded the lowest yield but the significantly highest protein content (39.06%). The interaction of 2nd week of February × GS-4 gave the highest seed yield (1358 kg/ha) and haulm yield (1916 kg/ha). Oil and protein content were not significantly influenced by sowing date. Economic analysis revealed that the 2nd week of February recorded the highest net returns (₹44,720/ha) and benefit-cost ratio (1.85), and among varieties GS-4 was most profitable (₹38,562/ha; B:C 1.73). The results indicate that sowing summer soybean in the 2nd week of February with variety GS-4 or GJS-3 is the most productive and profitable option for the south Saurashtra region of Gujarat.

Keywords: Summer soybean, sowing dates, varieties, growth, yield, quality.

1. Introduction

Soybean (*Glycine max* L.), the “miracle crop” of the 21st century, is an industrially important oilseed-cum-pulse crop whose dry seed contains nearly 40 per cent protein and 20 per cent oil, along with dietary fibre, calcium, phosphorus, iron and B-complex vitamins (Hammond *et al.*, 2005; Hou *et al.*, 2009) [10, 11]. It is also a rich source of polyunsaturated fatty acids and minerals, and its cultivation additionally builds soil fertility through symbiotic atmospheric nitrogen fixation (Devi *et al.*, 2012) [7]. Global soybean production stood at 426.82 million tonnes during 2025-26, with five countries-the USA, Brazil, Argentina, China and India-together accounting for more than 87 per cent of world output (Anonymous, 2026a) [1]. India produced 12.50 million tonnes from 11.83 million hectares at a productivity of 1056 kg/ha, with Madhya Pradesh, Maharashtra, Rajasthan, Karnataka and Gujarat as the leading states (Anonymous, 2026b) [2]. Within Gujarat, the Saurashtra region leads soybean cultivation, and the state ranked fifth nationally with a production of 5.10 lakh tonnes and a productivity of about 1697 kg/ha during 2024-25, well above the national average (Anonymous, 2026c) [3].

Time of sowing is one of the most decisive agronomic factors governing soybean performance. Early planting can lengthen the reproductive phase and improve dry matter accumulation during seed filling, but sowing too early exposes the crop to low soil temperature and delayed germination, whereas delayed sowing curtails vegetative growth and compresses flowering and pod filling, with reported yield losses of 17 to 43 kg/ha for every day of delay beyond the optimum window. Photoperiod and temperature together regulate both the onset of flowering and the duration of vegetative growth in soybean, so that deviation from the optimum sowing window in

either direction can compromise yield and grain quality (Berger *et al.*, 2014) ^[5]. Variety selection is equally important; GJS-3 and GS-4 are recent high-yielding releases of Junagadh Agricultural University recommended for cultivation in Gujarat, and matching such varieties with the appropriate sowing window is essential for realising their full yield potential. Despite growing interest in summer soybean in the Saurashtra region, information on the most suitable sowing time and variety for this specific agro-climatic condition remains limited. The present investigation was therefore undertaken to study the effect of sowing dates and varieties, including their interaction, on the growth, yield attributes, yield, quality and economics of summer soybean under south Saurashtra conditions of Gujarat.

2. Materials and Methods

2.1 Experimental site, season and soil

A field experiment was conducted during the summer seasons of 2023 and 2024 at Sagadividi Farm, Department of Seed Science and Technology, College of Agriculture, Junagadh Agricultural University, Junagadh (21.5° N latitude, 70.5° E longitude, 60 m above mean sea level), which falls under the South Saurashtra Agro-climatic Zone of Gujarat. The soil of the experimental site was clayey in texture and mildly alkaline in reaction (pH 7.9-8.0, EC 0.52-0.57 dS/m), medium in organic carbon (0.63-0.68%) and in available phosphorus (24.6-26.7 kg/ha) and potassium (247-250 kg/ha), but low in available nitrogen (230-233 kg/ha).

2.2 Treatments and experimental design

The experiment comprised 12 treatment combinations of three sowing dates as the main-plot treatment-T1: 4th week of January, T2: 2nd week of February and T3: 4th week of February and four soybean varieties as the sub-plot treatment-V1: GJS-3, V2: GS-4, V3: NRC-138 and V4: Phule Sangam-laid out in a Split Plot Design with three replications (gross plot 5.0 m × 3.6 m; net plot 4.0 m × 2.7 m). Seed was sown at a rate of 60 kg/ha with a spacing of 45 cm × 10 cm, and a recommended dose of 30 kg N and 60 kg P₂O₅/ha was applied basally through urea and DAP. The crop received eight irrigations during its life span and was managed with recommended plant protection measures.

2.3 Observations recorded

Growth parameters, including initial and final plant population, plant height, and number of branches per plant, as well as yield attributes and yield parameters, including number of pods per plant, number of seeds per pod, test weight, seed yield, haulm yield, and harvest index, were recorded from five randomly selected and tagged plants in each net plot, following standard procedures. Dry weight per plant at 30 and 60 days after sowing (DAS) and at harvest, and the number of nodules per plant at 45 DAS, were recorded from the border rows on both sides of each plot. For dry weight estimation, five plants were collected at each sampling stage (30 DAS, 60 DAS, and maturity), sun-dried for two to three days, and subsequently oven-dried at 70°C until a constant weight was attained. The average dry weight was calculated and expressed as g/plant. Oil content was estimated on

a dry-weight basis using nuclear magnetic resonance (NMR) spectrophotometry against a standard reference sample (Tiwari *et al.*, 1974) ^[23]. Protein content was estimated using the micro-Kjeldahl method, and the nitrogen content was converted to protein using a conversion factor of 6.25 (Gassi *et al.*, 1973) ^[8]. The cost of cultivation, gross returns, net returns, and benefit-cost (B:C) ratio were calculated treatment-wise based on the prevailing market prices of the produce and inputs.

2.4 Statistical analysis

Data recorded during both years were statistically analysed separately and in pooled form following the analysis of variance technique for Split Plot Design as described by Gomez and Gomez (1984) ^[9]. Treatment means were compared using the critical difference (C.D.) at 5 per cent probability wherever the F-test was significant; “NS” denotes a non-significant effect.

3. Results and Discussion

3.1 Plant population

Time of sowing had no significant effect on either initial or final plant population in 2023, 2024 or in pooled analysis (Table 1), indicating that seedling establishment was unaffected across the three sowing windows, probably because soil temperature during January-February (22-30°C) remained within the optimum range for soybean germination. Varietal differences were also non-significant, although GS-4 recorded the numerically highest final population (212610 plants/ha, pooled), followed by GJS-3 (207011), Phule Sangam (202645) and NRC-138 (195515). The T × V interaction and year effects were non-significant. These results corroborate the findings of Kaushik *et al.* (2014) ^[14], Jaybhave *et al.* (2015) ^[13], Naidu *et al.* (2016) ^[16] and Prabhakar *et al.* (2018) ^[18].

3.2 Plant height

Time of sowing significantly influenced plant height at both 30 DAS and at harvest in both years and in pooled analysis (Table 1). The 4th week of January produced the tallest plants at 30 DAS (22.07 cm, pooled) and at harvest (32.20 cm), significantly taller than the 2nd week of February (19.78 and 29.72 cm) and the 4th week of February (17.94 and 27.99 cm), with a consistent decline as sowing was delayed. Among varieties, GS-4 (21.52 cm at 30 DAS; 31.72 cm at harvest) remained at par with GJS-3 and was significantly taller than NRC-138, the shortest variety at both stages. The T × V interaction and year effects were non-significant. The greater height under early sowing is attributable to the moderate temperature prevailing during the vegetative phase of January-sown crops, which favoured a longer period of internode elongation, whereas the rising temperature and photoperiod under late February sowing compressed the vegetative phase. The taller stature of GS-4 and GJS-3 reflects their inherently greater vegetative vigour. These findings agree with Rekha and Dhurua (2010) ^[20], Hu and Wiatrak (2012) ^[12], Naidu *et al.* (2016) ^[16], Nath *et al.* (2017) ^[17], and Raghuwanshi *et al.* (2017) ^[19].

Table 1: Effect of time of sowing and variety on plant height at 30 DAS and at harvest in summer soybean

Treatments	Plant height at 30 DAS (cm)			Plant height at harvest (cm)		
	2023	2024	Pooled	2023	2024	Pooled
Time of sowing (T)						
T1: 4 th Week of January	22.27	21.87	22.07	32.01	32.40	32.20
T2: 2 nd Week of February	19.71	19.84	19.78	28.87	30.57	29.72
T3: 4 th Week of February	18.46	17.42	17.94	28.28	27.70	27.99
S.Em.±	0.63	0.76	0.49	0.76	0.90	0.59
C.D. at 5 %	2.48	2.99	1.61	2.97	3.53	1.92
CV (%)	10.85	13.38	12.15	8.83	10.30	9.60
Variety (V)						
V1: GJS-3	21.67	20.44	21.05	30.39	30.77	30.58
V2: GS-4	21.78	21.27	21.52	31.36	32.08	31.72
V3: NRC-138	17.83	18.01	17.92	27.40	29.47	28.43
V4: Phule Sangam	19.31	19.13	19.22	29.73	28.57	29.15
S.Em.±	0.52	0.57	0.38	0.48	0.74	0.44
C.D. at 5 %	1.54	1.70	1.10	1.43	2.19	1.26
CV (%)	7.69	8.69	8.20	4.85	7.33	6.24
Interaction (T × V)						
S.Em.±	0.90	0.99	0.94	0.83	1.28	1.08
C.D. at 5 %	NS	NS	NS	NS	NS	NS

Table 2: Effect of time of sowing and varieties on plant height at 30 days after sowing (DAS) and at harvest of soybean during 2023 and 2024, with pooled analysis

Treatments	Plant height at 30 DAS (cm)			Plant height at harvest (cm)		
	2023	2024	Pooled	2023	2024	Pooled
Time of sowing (T)						
T ₁ : 4 th Week of January	22.27	21.87	22.07	32.01	32.40	32.20
T ₂ : 2 nd Week of February	19.71	19.84	19.78	28.87	30.57	29.72
T ₃ : 4 th Week of February	18.46	17.42	17.94	28.28	27.70	27.99
S.Em.±	0.63	0.76	0.49	0.76	0.90	0.59
C.D. at 5 %	2.48	2.99	1.61	2.97	3.53	1.92
CV (%)	10.85	13.38	12.15	8.83	10.30	9.60
Variety (V)						
V ₁ : GJS-3	21.67	20.44	21.05	30.39	30.77	30.58
V ₂ : GS-4	21.78	21.27	21.52	31.36	32.08	31.72
V ₃ : NRC-138	17.83	18.01	17.92	27.40	29.47	28.43
V ₄ : Phule Sangam	19.31	19.13	19.22	29.73	28.57	29.15
S.Em.±	0.52	0.57	0.38	0.48	0.74	0.44
C.D. at 5 %	1.54	1.70	1.10	1.43	2.19	1.26
CV (%)	7.69	8.69	8.20	4.85	7.33	6.24
Interaction (T × V)						
S.Em.±	0.90	0.99	0.94	0.83	1.28	1.08
C.D. at 5 %	NS	NS	NS	NS	NS	NS
Year (Y)						
S.Em.±	0.40			0.48		
C.D. at 5 %	NS			NS		
Year interactions						
	T × Y	V × Y	T × V × Y	T × Y	V × Y	T × V × Y
S.Em.±	0.70	0.54	0.94	0.83	0.62	1.08
C.D. at 5 %	NS	NS	NS	NS	NS	NS

NS = Non-significant. Year (Y) and year × treatment interaction effects were non-significant for both stages.

3.3 Number of branches per plant and nodules per plant

Time of sowing significantly influenced branching in pooled analysis, with the 2nd week of February recording the highest number of branches per plant (3.57, pooled), followed by the 4th week of January (3.44) and the 4th week of February (3.24) (Table 2). Among varieties, GS-4 produced significantly more branches (4.01) than GJS-3 (3.71), Phule Sangam (3.48) and NRC-138 (2.48), the last being the most compact and least-branched variety. Nodulation at 45 DAS, in contrast, was governed by sowing date rather than variety: the 4th week of January recorded the significantly highest nodule number (46.82, pooled), significantly

more than the 2nd week of February (43.41) and the 4th week of February (42.22), while varietal and interaction effects on nodulation were non-significant. The greater branching in GS-4 reflects its comparatively indeterminate growth habit, while the higher nodulation under early sowing is consistent with the moderate soil temperature at that time favouring *Bradyrhizobium* infection and nodule development. These results are in line with Singh *et al.* (2014) ^[22], Jaybhaye *et al.* (2015) ^[13], Kaushik *et al.* (2014) ^[14], Naidu *et al.* (2016) ^[16] and Raghuwanshi *et al.* (2017) ^[19].

Table 3: Effect of time of sowing and variety on number of branches per plant at harvest and number of nodules per plant at 45 DAS in summer soybean

Treatments	Branches per plant at harvest			Nodules per plant at 45 DAS		
	2023	2024	Pooled	2023	2024	Pooled
Time of sowing (T)						
T1: 4 th Week of January	3.44	3.45	3.44	46.84	46.79	46.82
T2: 2 nd Week of February	3.58	3.55	3.57	43.41	43.41	43.41
T3: 4 th Week of February	3.21	3.27	3.24	42.12	42.31	42.22
S.Em.±	0.08	0.13	0.08	0.92	0.86	0.63
C.D. at 5 %	NS	NS	NS	3.62	3.36	2.05
CV (%)	8.47	13.37	11.20	7.24	6.71	6.98
Variety (V)						
V1: GJS-3	3.75	3.67	3.71	45.03	44.29	44.66
V2: GS-4	4.00	4.01	4.01	46.54	44.68	45.61
V3: NRC-138	2.51	2.45	2.48	42.42	43.81	43.11
V4: Phule Sangam	3.37	3.58	3.48	42.52	43.90	43.21
S.Em.±	0.08	0.10	0.06	1.15	0.86	0.72
C.D. at 5 %	0.23	0.31	0.19	NS	NS	NS
CV (%)	6.90	9.05	8.05	7.79	5.85	6.89
Interaction (T × V)						
S.Em.±	0.14	0.18	0.16	1.98	1.49	1.76
C.D. at 5 %	NS	NS	NS	NS	NS	NS

NS = Non-significant. Year (Y) and year × treatment interaction effects were non-significant for both traits.

3.4 Dry weight per plant

Dry weight per plant was significantly influenced by time of sowing at 30 DAS, 60 DAS and at harvest in both years and in pooled analysis (Table 3). The 2nd week of February recorded the highest dry weight at 30 DAS (1.69 g, pooled), but by 60 DAS and at harvest the 4th week of January took the lead (9.96 g and 16.16 g, respectively; at par with the 2nd week of February at harvest), while the 4th week of February recorded the lowest dry weight at all three stages owing to its shortened vegetative period. Among varieties, differences were non-significant at 30 DAS, but by 60 DAS Phule Sangam accumulated significantly more dry

weight (11.36 g) than the rest, and at harvest GS-4 (15.63 g) and GJS-3 (15.53 g) were at par and significantly heavier than Phule Sangam and NRC-138, the last recording the lowest dry weight throughout. Interaction and year effects were non-significant at all stages. The early warmth of February favoured rapid initial growth, whereas the longer photosynthetically active period of January-sown crops translated into greater biomass by harvest. These findings agree with Kaushik *et al.* (2014) [14], Singh *et al.* (2014) [22], Naidu *et al.* (2016) [16], Raghuwanshi *et al.* (2017) [19], and Vadhavana (2026) [25].

Table 4: Effect of time of sowing and variety on dry weight per plant at 30 DAS, 60 DAS and at harvest in summer soybean

Treatments	Dry weight/plant at 30 DAS (g)			Dry weight/plant at 60 DAS (g)			Dry weight/plant at harvest (g)		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
Time of sowing (T)									
T1: 4 th Week of January	0.89	0.96	0.92	9.84	10.07	9.96	16.04	16.28	16.16
T2: 2 nd Week of February	1.64	1.74	1.69	9.22	9.42	9.32	15.87	15.98	15.93
T3: 4 th Week of February	0.93	1.01	0.97	8.30	7.93	8.12	12.47	11.63	12.05
S.Em.±	0.05	0.04	0.03	0.24	0.12	0.13	0.46	0.46	0.32
C.D. at 5 %	0.18	0.17	0.10	0.93	0.48	0.43	1.80	1.81	1.06
CV (%)	13.85	11.90	12.85	8.96	4.59	7.11	10.71	10.91	10.81
Variety (V)									
V1: GJS-3	1.14	1.23	1.19	8.36	8.73	8.54	15.49	15.56	15.53
V2: GS-4	1.16	1.24	1.20	9.74	9.90	9.82	15.56	15.69	15.63
V3: NRC-138	1.11	1.18	1.14	6.60	6.99	6.79	13.50	13.51	13.50
V4: Phule Sangam	1.20	1.29	1.24	11.78	10.95	11.36	14.62	13.77	14.20
S.Em.±	0.06	0.04	0.04	0.27	0.31	0.21	0.51	0.58	0.38
C.D. at 5 %	NS	NS	NS	0.79	0.93	0.59	1.51	1.71	1.10
CV (%)	15.85	10.57	13.30	8.73	10.27	9.54	10.32	11.82	11.09
Interaction (T × V)									
S.Em.±	0.11	0.08	0.09	0.46	0.54	0.50	0.88	1.00	0.94
C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS = Non-significant. Year (Y) and year × treatment interaction effects were non-significant at all three stages.

3.5 Number of pods per plant and number of seeds per pod

Time of sowing significantly influenced the number of pods per plant, with the 2nd week of February recording significantly more pods (37.11, pooled) than the 4th week of January (31.86) and the

4th week of February (24.01), the last being the lowest (Table 4). Among varieties, GS-4 (33.86) remained at par with GJS-3 (32.03) and was significantly superior to Phule Sangam (29.26) and NRC-138 (28.82, the lowest). Number of seeds per pod,

however, was not significantly affected by either sowing date or variety, indicating that this trait is governed more by genetic constitution than by sowing environment. Interaction effects were non-significant for both traits. The higher pod number under the 2nd week of February reflects the favourable temperature and photoperiod combination available during flowering and pod set,

whereas late sowing exposed the crop to rising temperature during this critical stage, increasing flower and pod abortion. These results agree with Kaushik *et al.* (2014) ^[14], Jaybhaye *et al.* (2015) ^[13], Naidu *et al.* (2016) ^[16], Kundu *et al.* (2016) ^[15], and Raghuwanshi *et al.* (2017) ^[19].

Table 5: Effect of time of sowing and variety on number of pods per plant and number of seeds per pod in summer soybean

Treatments	Number of pods per plant			Number of seeds per pod		
	2023	2024	Pooled	2023	2024	Pooled
Time of sowing (T)						
T1: 4 th Week of January	30.74	32.99	31.86	2.61	2.57	2.59
T2: 2 nd Week of February	35.19	39.03	37.11	2.71	2.75	2.73
T3: 4 th Week of February	24.12	23.90	24.01	2.68	2.85	2.76
S.Em.±	1.13	0.94	0.73	0.11	0.10	0.07
C.D. at 5 %	4.43	3.69	2.40	NS	NS	NS
CV (%)	13.03	10.18	11.61	13.75	12.49	13.12
Variety (V)						
V1: GJS-3	30.65	33.42	32.03	2.64	2.68	2.66
V2: GS-4	32.78	34.94	33.86	2.79	2.76	2.78
V3: NRC-138	28.11	29.53	28.82	2.46	2.59	2.52
V4: Phule Sangam	28.53	30.00	29.26	2.78	2.85	2.81
S.Em.±	1.04	0.82	0.66	0.10	0.12	0.08
C.D. at 5 %	3.09	2.45	1.90	NS	NS	NS
CV (%)	10.39	7.73	9.08	11.45	12.74	12.13
Interaction (T × V)						
S.Em.±	1.80	1.43	1.63	0.18	0.20	0.19
C.D. at 5 %	NS	NS	NS	NS	NS	NS

NS = Non-significant. Year (Y) and year × treatment interaction effects were non-significant for both traits.

3.6 Test weight and harvest index

Test weight (100-seed weight) was not significantly influenced by time of sowing, though the 2nd week of February recorded a marginally higher value (11.01 g, pooled) (Table 5). Varietal differences were significant, with GJS-3 recording the significantly highest test weight (12.05 g), followed by Phule Sangam (11.29 g), while GS-4 and NRC-138 were at par and lowest (10.33 and 10.22 g). Harvest index was not significantly affected by either sowing date or variety, with values ranging narrowly from 38.97 to 41.33 per cent across sowing dates and from 39.80 to 40.21 per cent across varieties, indicating that seed

and haulm yield were altered proportionately under the different treatments. Interaction effects were non-significant for both traits. The stable test weight across sowing dates reflects a compensatory mechanism in soybean whereby a reduction in pod number is partly offset by maintenance of individual seed size, while the consistently heavier seed of GJS-3 reflects its genetic capacity for greater assimilate accumulation per seed. These findings agree with Kaushik *et al.* (2014) ^[14], Singh *et al.* (2014) ^[22], Kundu *et al.* (2016) ^[15], Raghuwanshi *et al.* (2017) ^[19], and Prabhakar *et al.* (2018) ^[18].

Table 6: Effect of time of sowing and variety on test weight and harvest index in summer soybean

Treatments	Test weight, 100-seed (g)			Harvest index (%)		
	2023	2024	Pooled	2023	2024	Pooled
Time of sowing (T)						
T1: 4 th Week of January	10.93	10.91	10.92	39.27	40.27	39.77
T2: 2 nd Week of February	11.00	11.02	11.01	41.18	41.48	41.33
T3: 4 th Week of February	10.99	10.97	10.98	38.57	39.36	38.97
S.Em.±	0.30	0.33	0.23	0.84	0.80	0.58
C.D. at 5 %	NS	NS	NS	NS	NS	NS
CV (%)	9.60	10.48	10.05	7.30	6.90	7.10
Variety (V)						
V1: GJS-3	12.16	11.94	12.05	40.18	40.24	40.21
V2: GS-4	10.26	10.39	10.33	39.90	40.49	40.19
V3: NRC-138	10.15	10.29	10.22	39.21	40.39	39.80
V4: Phule Sangam	11.33	11.24	11.29	39.41	40.36	39.89
S.Em.±	0.29	0.38	0.24	0.82	0.81	0.58
C.D. at 5 %	0.87	1.13	0.69	NS	NS	NS
CV (%)	8.03	10.42	9.30	6.21	6.00	6.10
Interaction (T × V)						
S.Em.±	0.51	0.66	0.59	1.42	1.40	1.41
C.D. at 5 %	NS	NS	NS	NS	NS	NS

NS = Non-significant. Year (Y) and year × treatment interaction effects were non-significant for both traits.

3.7 Seed yield, haulm yield and their interaction with variety

Seed yield and haulm yield were significantly influenced by time of sowing, variety and their interaction in both years and in pooled analysis (Table 6). The 2nd week of February recorded the significantly highest seed yield (1322 kg/ha, pooled) and haulm yield (1876 kg/ha, at par with the 4th week of January), both significantly superior to the 4th week of February (866 and 1355 kg/ha, respectively), the lowest for both traits. Among varieties, GS-4 (1238 kg/ha seed yield; 1838 kg/ha haulm yield) remained at par with GJS-3 (1225 and 1816 kg/ha) and was significantly superior to Phule Sangam and NRC-138, the last recording the lowest yield of both.

The T × V interaction was significant for both traits (Tables 7 and 8): the combination of 2nd week of February × GS-4 recorded the significantly highest seed yield (1358 kg/ha, pooled; at par with

T2V1, T2V4 and T2V3) and haulm yield (1916 kg/ha, at par with T2V1, T1V2 and T1V1), while the 4th week of February × NRC-138 recorded the lowest seed yield (605 kg/ha) and haulm yield (956 kg/ha). The superior yield under the 2nd week of February reflects the greater pod number and favourable temperature during reproductive growth that enhanced photosynthate translocation to the developing seed, whereas the longer vegetative duration of January- and February-sown crops favoured greater haulm accumulation; delayed sowing under the 4th week of February shortened both phases and curtailed yield. These findings agree with Kaushik *et al.* (2014) ^[14], Jaybhaye *et al.* (2015) ^[13], Naidu *et al.* (2016) ^[16], Kundu *et al.* (2016) ^[15], Raghuwanshi *et al.* (2017) ^[19], Dakhore *et al.* (2024) ^[6], and Vadhavana (2026) ^[25].

Table 7: Effect of time of sowing and variety on seed yield and haulm yield in summer soybean

Treatments	Seed yield (kg/ha)			Haulm yield (kg/ha)		
	2023	2024	Pooled	2023	2024	Pooled
Time of sowing (T)						
T1: 4 th Week of January	1202	1255	1228	1857	1863	1860
T2: 2 nd Week of February	1311	1332	1322	1874	1877	1876
T3: 4 th Week of February	861	871	866	1364	1347	1355
S.Em.±	30.82	33.31	22.69	53.74	39.30	33.29
C.D. at 5 %	121	131	74	211	154	109
CV (%)	9.49	10.01	9.76	10.96	8.03	9.61
Variety (V)						
V1: GJS-3	1222	1227	1225	1815	1817	1816
V2: GS-4	1232	1244	1238	1853	1823	1838
V3: NRC-138	997	1036	1016	1532	1518	1525
V4: Phule Sangam	1047	1104	1076	1593	1624	1609
S.Em.±	28.67	25.47	19.17	39.41	42.97	29.15
C.D. at 5 %	85	76	55	117	128	84
CV (%)	7.65	6.63	7.14	6.96	7.60	7.29
Interaction (T × V)						
S.Em.±	49.65	44.12	46.97	68.26	74.42	71.41
C.D. at 5 %	148	131	135	203	221	205

Year (Y) effects were non-significant for both traits; the T × V interaction (shown in Tables 8 and 9) was significant.

Table 8: Interaction effect of time of sowing and variety on seed yield (kg/ha) in summer soybean

Variety	2023			2024			Pooled		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
V1: GJS-3	1252	1339	1074	1270	1349	1063	1261	1344	1069
V2: GS-4	1262	1350	1085	1271	1366	1095	1266	1358	1090
V3: NRC-138	1119	1277	594	1215	1276	616	1167	1277	605
V4: Phule Sangam	1173	1279	689	1264	1338	710	1219	1309	699
S.Em.±	49.65			44.12			46.97		
C.D. at 5 %	148			131			135		
CV (%)	7.65			6.63			7.14		

S.Em.±, C.D. at 5% and CV (%) values apply to the T × V interaction within each year/pooled column-group (2023, 2024, Pooled respectively).

Table 9: Interaction effect of time of sowing and variety on haulm yield (kg/ha) in summer soybean

Variety	2023			2024			Pooled		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
V1: GJS-3	1880	1901	1664	1877	1908	1667	1879	1904	1666
V2: GS-4	1917	1927	1714	1897	1905	1669	1907	1916	1691
V3: NRC-138	1839	1793	965	1778	1827	947	1809	1810	956
V4: Phule Sangam	1792	1877	1111	1899	1869	1105	1846	1873	1108
S.Em.±	68.26			74.42			71.41		
C.D. at 5 %	203			221			205		
CV (%)	6.96			7.60			7.29		

S.Em.±, C.D. at 5% and CV (%) values apply to the T × V interaction within each year/pooled column-group (2023, 2024, Pooled respectively).

3.8 Oil content and protein content

Oil content was not significantly influenced by time of sowing or

variety, or by their interaction, in either year or pooled analysis, though GS-4 recorded the numerically highest oil content

(19.41%, pooled) (Table 9). Protein content was likewise unaffected by sowing date, but varieties differed significantly: NRC-138 recorded the significantly highest protein content (39.06%, pooled), well above GS-4 (36.55%), GJS-3 (36.29%) and Phule Sangam (36.00%), which were mutually at par. The stability of oil content across sowing dates indicates that oil accumulation is governed primarily by genetic constitution rather

than sowing-induced environmental variation, while the markedly higher protein in NRC-138, despite its lower yield, reflects its distinct nitrogen-metabolism efficiency and illustrates the well-documented inverse relationship between oil and protein content in soybean. These results agree with Bellaloui *et al.* (2011) ^[4], Vyas and Khandwe (2014) ^[26], Kundu *et al.* (2016) ^[15], Prabhakar *et al.* (2018) ^[18], and Shahin *et al.* (2023) ^[21].

Table 10: Effect of time of sowing and variety on oil content and protein content in summer soybean

Treatments	Oil content (%)			Protein content (%)		
	2023	2024	Pooled	2023	2024	Pooled
Time of sowing (T)						
T1: 4 th Week of January	19.14	19.13	19.14	36.97	37.08	37.03
T2: 2 nd Week of February	19.32	19.22	19.27	36.80	37.27	37.03
T3: 4 th Week of February	19.29	19.19	19.24	37.26	36.46	36.86
S.Em.±	0.12	0.15	0.10	0.49	0.55	0.37
C.D. at 5 %	NS	NS	NS	NS	NS	NS
CV (%)	2.23	2.78	2.52	4.56	5.16	4.87
Variety (V)						
V1: GJS-3	19.26	19.31	19.29	36.39	36.19	36.29
V2: GS-4	19.53	19.30	19.41	36.61	36.48	36.55
V3: NRC-138	19.20	19.11	19.15	39.13	38.99	39.06
V4: Phule Sangam	19.01	19.00	19.01	35.90	36.09	36.00
S.Em.±	0.15	0.14	0.10	0.45	0.42	0.31
C.D. at 5 %	NS	NS	NS	1.33	1.24	0.88
CV (%)	2.40	2.18	2.29	3.62	3.40	3.51
Interaction (T × V)						
S.Em.±	0.27	0.24	0.25	0.77	0.73	0.75
C.D. at 5 %	NS	NS	NS	NS	NS	NS

NS = Non-significant. Year (Y) and year × treatment interaction effects were non-significant for both traits.

3.9 Economics

Economic analysis based on the mean of both years showed that the 2nd week of February recorded the highest gross returns (₹97,230/ha), net returns (₹44,720/ha) and benefit-cost ratio (1.85), followed by the 4th week of January (₹90,610, ₹37,734/ha and 1.71); the 4th week of February was the least remunerative (₹64,008, ₹11,498/ha and 1.22) despite an almost identical cost of cultivation to the 2nd week of February (Table 10). Among varieties, GS-4 gave the highest net returns (₹38,562/ha) and B:C

ratio (1.73), closely followed by GJS-3 (₹37,597/ha; 1.71), while NRC-138 was the least profitable (₹22,240/ha; 1.42) despite a uniform cost of cultivation (₹52,693/ha) across varieties. The superior economic performance of the 2nd week of February and of GS-4/GJS-3 tracked their higher seed yield, confirming that both the choice of sowing time and variety are decisive for the profitability of summer soybean cultivation in this region. These findings corroborate Kaushik *et al.* (2014) ^[14], Tomar *et al.* (2014) ^[24], Jaybhaye *et al.* (2015) ^[13], and Naidu *et al.* (2016) ^[16].

Table 11: Economics of summer soybean cultivation as influenced by time of sowing and variety (mean of 2023 and 2024)

Treatments	Gross returns (₹/ha)	Cost of cultivation (₹/ha)	Net returns (₹/ha)	B:C ratio
Time of sowing (T)				
T1: 4 th Week of January	90610	52876	37734	1.71
T2: 2 nd Week of February	97230	52510	44720	1.85
T3: 4 th Week of February	64008	52510	11498	1.22
Variety (V)				
V1: GJS-3	90290	52693	37597	1.71
V2: GS-4	91255	52693	38562	1.73
V3: NRC-138	74933	52693	22240	1.42
V4: Phule Sangam	79343	52693	26650	1.51

Economics was computed on the mean of two years; formal ANOVA/C.D. was not applied to these derived monetary values.

4. Conclusion

Based on the two-year field experiment, sowing summer soybean in the 2nd week of February, combined with the variety GS-4, consistently produced the best combination of pod number, seed yield, haulm yield and economic return, and the interaction of the 2nd week of February × GS-4 gave the single highest seed and haulm yield among all treatment combinations. NRC-138, while the lowest yielding, was distinguished by significantly higher seed protein content and may be considered where quality rather than yield is the priority. For higher productivity and profitability of summer soybean under south Saurashtra conditions of Gujarat,

sowing in the 2nd week of February with variety GS-4 is advisable.

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Author contributions

D. V. Savaliya conceptualised and designed the field experiment, supervised data collection and finalised the manuscript. S. P. Kachhadiya contributed to experimental design and provided

agrometeorological expertise. A. R. Trambadiya and R. V. Kalaria assisted with field data collection, laboratory analysis and statistical analysis. All authors read, critically reviewed and approved the final manuscript.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics approval

This study did not involve human data or animals so, therefore did not require approval from an institutional ethical committee clearance. The field experiment was conducted in accordance with the standard agronomic research protocols of Junagadh Agricultural University, Junagadh.

AI tool usage declaration

No generative AI or AI-assisted technologies were used in the writing, analysis, or preparation of this manuscript.

References

1. Anonymous. The Soybean Processors Association of India, Indore. 2026a. Available at: <https://sopa.org/world-soybean-production/>. Accessed 2026 Apr 6.
2. Anonymous. The Soybean Processors Association of India, Government of India. 2026b. Available at: <https://sopa.org/all-india-state-wise-soybean-area-production-and-productivity/>. Accessed 2026 Apr 6.
3. Anonymous. Final advance estimates of area, production and yield of major kharif/rabi/summer crops of Gujarat state for the year 2024-25. Directorate of Agriculture, Government of Gujarat, Gujarat. 2026c. Available at: <https://dag.gujarat.gov.in/Home/AreaProductionAndYield>. Accessed 2026 Apr 6.
4. Bellaloui N, Reddy KN, Gillen AM, Fisher DK, Mengistu A. Influence of planting date on seed protein, oil sugars, minerals and nitrogen metabolism in soybean under irrigated and non-irrigated environments. *American Journal of Plant Sciences*. 2011;2(5):702-715.
5. Berger DJ, Zhang B, Smith SF, Chen P. Planting date, irrigation and row spacing effects on agronomic traits of food-grade soybean. *Advances in Crop Science and Technology*. 2014;2(4):1-8.
6. Dakhore KK, Kadam YE, Kadam DR, Mane RB, Kapse PS, Bal SK. Crop-weather relationship of soybean in Marathwada region of Maharashtra. *Journal of Agrometeorology*. 2024;26(2):163-167.
7. Devi KN, Singh LN, Singh MS, Singh SB, Singh KK. Influence of sulphur and boron fertilization on yield, quality, nutrient uptake and economics of soybean (*Glycine max*) under upland conditions. *Journal of Agricultural Science*. 2012;4(4):1-10.
8. Gassi S, Tikoo JL, Banerjee SK. Changes in protein and methionine content in the maturing seeds of legumes. *Seed Research*. 1973;1:104-106.
9. Gomez K, Gomez A. Statistical procedures for agricultural research. 2nd ed. New York: John Wiley and Sons; 1984.
10. Hammond EG, Johnson LA, Caiping S, Wang T, White PJ. Soybean oil. Iowa State University, Ames, Iowa. 2005;6(4):577-641.
11. Hou A, Chen P, Alloatti J, Li D, Mozzoni L, Zhang B, Shi A. Genetic variability of sugar content in worldwide soybean germplasm collections. *Crop Science*. 2009;49(3):903-912.
12. Hu M, Wiatrak P. Effect of planting date on soybean growth, yield and grain quality: review. *Agronomy Journal*. 2012;104(3):785-790.
13. Jaybhaye PR, Shinde PB, Asewar BV. Response of soybean to sowing dates and spacing under rainfed conditions. *International Journal of Tropical Agriculture*. 2015;33(2):747-750.
14. Kaushik DK, Chandrawanshi SK, Patel SR, Lakpale R, Chaudhary J. Effect of sowing date and types of varieties on yield attributes of soybean in the Chhattisgarh plains zone. *Ecology, Environment & Conservation*. 2014;20(Suppl.):S237-S240.
15. Kundu PK, Roy TS, Khan MSH, Parvin K, Mazed HEMK. Effect of sowing date on yield and seed quality of soybean. *Journal of Agriculture and Ecology Research International*. 2016;9(4):1-7.
16. Naidu RC, Rao VUM, Pankaj PK, Sarada C. Influence of sowing dates and varieties on growth and yield of soybean (*Glycine max* L. Merrill). *Journal of Agrometeorology*. 2016;18(Special Issue):75-79.
17. Nath A, Karunakar AP, Kumar A, Nagar RK. Effect of sowing dates and varieties on soybean performance in Vidarbha region of Maharashtra, India. *Journal of Applied and Natural Science*. 2017;9(1):544-550.
18. Prabhakar K, Padmalatha Y, Venkataramanamma K, Muniratnam P, Radhakrishnamurthy V. Seed yield and quality of soybean [*Glycine max* (L.) Merrill] as influenced by cultivar and sowing date in vertisols of Andhra Pradesh during kharif season. *Legume Research*. 2018;41(2):281-286.
19. Raghuwanshi S, Vyas MD, Maravi PS. Effect of sowing dates on growth, yield attributes and productivity of soybean [*Glycine max* (L.) Merrill] genotypes under rainfed conditions. *Soybean Research*. 2017;15(2):58-60.
20. Rekha MS, Dhurua S. Effect of sowing time on performance of soybean, *Glycine max* (L.) Merrill varieties during rabi and summer in vertisols. *Global Journal of Science Frontier Research*. 2010;14(3):41-45.
21. Shahin MG, Saudy HS, El-Bially ME, El-Momen WRA, El-Gabry YA, El-Samad GAA, Sayed AN. Physiological and agronomic responses and nutrient uptake of soybean genotypes cultivated under various sowing dates. *Journal of Soil Science and Plant Nutrition*. 2023;23:5145-5158.
22. Singh G, Kaur H, Gill KK. Influence of diverse environments on the growth and productivity of soybean genotypes in Northern India. *Soybean Research*. 2014;(Special Issue):60-66.
23. Tiwari L, Gara RC, Sing I. Mineral nutrition in higher plants. Orlando, FL: Academic Press; 1974.
24. Tomar DS, Chauhan S, Tiwari R, Saxena AK. Effect of environmental variation and phosphorus nutrition on the performance and economics of soybean cultivars of Central India. *Journal of Krishi Vigyan*. 2014;3(1):18-23.
25. Vadhavana SB. Thermal requirements of summer soybean varieties under varying weather conditions [M.Sc. thesis]. Junagadh, India: Department of Agronomy, Junagadh Agricultural University; 2026.
26. Vyas MD, Khandwe R. Effect of row spacing and seed rate on morpho-physiological parameters, yield attributes and productivity of soybean cultivars under rainfed condition of Vindhya plateau of Madhya Pradesh. *Soybean Research*. 2014;(Special Issue):82-91.