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Interactive effects of sowing windows, sowing depths and moisture management practices on yield parameters of soybean [*Glycine max* (L.) Merrill] under rainfed conditions

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Abstract
A field experiment was conducted during *Kharif* 2024 at the MARS, UAS Dharwad, to investigate the interactive effects of sowing windows, sowing depths, and moisture management practices on yield of soybean [*Glycine max* (L.) Merrill] under rainfed conditions. The study was laid out in a factorial RCBD with three sowing windows (10 July, 5 August, 9 September), two depths (5 cm and 10 cm), and two moisture regimes (with and without mulch). Soil temperature and moisture dynamics varied significantly across treatments. Early sowing on 10 July maintained higher soil temperature (25.1°C) and favorable moisture (22.4%), which facilitated better germination, crop establishment, and root development. Sowing at 5 cm depth ensured quicker germination and higher vigor due to warmer soils, whereas 10 cm depth favored moisture conservation, supporting later growth. Mulching increased soil temperature but reduced soil moisture, while without mulch preserved higher moisture during reproductive stages. Yield attributes were strongly influenced by treatments. July 10 sowing consistently outperformed later dates, recording maximum pods per plant (40.33), seed yield (2199 kg ha^{-1}), and haulm yield (2578 kg ha^{-1}). Interaction effects revealed that July 10 sowing at 5 cm depth with mulch produced the highest pod number (44.67), seed yield (2413 kg ha^{-1}), and haulm yield (2651 kg ha^{-1}). Delayed sowing in September reduced yield drastically due to shortened season and lower soil temperature. Overall, early sowing, shallow depth, and suitable moisture management optimized the soil environment and enhanced soybean yield under rainfed conditions.

Keywords: Soybean, sowing windows, sowing depths, moisture management

Introduction
Soybean [*Glycine max* (L.) Merrill] is one of the most important legume oilseed crops, valued for its high protein and oil content, contributing significantly to global food, feed and industrial sectors. In India, soybean has emerged as leading *Kharif* crop, occupying 11-13 million hectares annually under rainfed ecosystems, particularly in central and peninsular regions. Despite its potential, soybean productivity remains low and unstable compared to global averages, primarily due to the influence of climatic and edaphic factors. Among these, soil temperature plays pivotal role in regulating seed germination, root development, nutrient uptake, photosynthesis and ultimately crop yield.
Sowing window, sowing depth and soil moisture availability are key agronomic factors that interact with soil temperature to determine the success of soybean establishment and productivity. Early or delayed sowing alters the thermal regime of the soil, directly influencing crop phenology and partitioning of assimilates. Similarly, sowing depth modifies the soil seed microenvironment by affecting germination rate, seedling vigor and root architecture. Moisture management practices such as mulching help in conserving soil moisture, moderating soil temperature fluctuations and improving water use efficiency under rainfed conditions. Hence, combined assessment of these factors is essential to optimize soybean growth and yield in variable climatic situations. Previous studies have highlighted the individual effects of soil temperature, sowing time and moisture management on soybean productivity;

however, limited research exists on their interactive impacts under rainfed conditions. Understanding these interactions is crucial for developing sustainable crop management strategies that ensure better crop establishment, enhanced yield attributes and improved resilience against weather variability.

Therefore, the present investigation entitled *"Interactive Effects of Sowing Windows, Sowing Depths and Moisture Management Practices on Yield Parameters of Soybean [Glycine max (L.) Merrill] under Rainfed Conditions"* was undertaken. The study aims to assess the influence of different sowing environments and management practices on soil temperature, growth and yield of soybean. The findings will contribute to identifying suitable crop establishment strategies for maximizing productivity and stability of soybean in rainfed conditions.

Materials and Methods

The field experiment was conducted during the *Kharif* season of 2024 at the MARS, UAS, Dharwad, Karnataka. The experimental site is situated at 15.49°N latitude, 74.98°E longitude, and 678 m above msl, falling under the Northern Transition Zone (Zone 8) of Karnataka. The soil of the experimental field was classified as black cotton soil *Vertisol* with clay loam texture. Pre-sowing soil analysis indicated a pH of 7.22, electrical conductivity of 0.33 dS m^{-1}, organic carbon content of 0.42%, and available nitrogen, phosphorus, and potassium of 234.8, 34.6, and 440.5 kg ha^{-1}, respectively.

The region experiences a semi-arid tropical climate with bimodal rainfall pattern. During the cropping season, a total rainfall of 941 mm was received, with major precipitation in July (240 mm) and October (249.2 mm). The mean maximum and minimum temperatures during the crop growth period were 31.5°C and 19.5°C, respectively. The experiment was laid out in a factorial randomized complete block design with three replications and twelve treatment combinations, consisting of three sowing windows (first fortnight of July, first fortnight of August, and first fortnight of September), two sowing depths (5 cm and 10 cm), and two moisture management practices (with mulching and without mulching). Soybean variety DSb-34 was used as the test crop. The gross and net plot sizes were 6.3 m × 5.0 m and 5.3 m × 4.0 m, respectively, with a spacing of 30 cm × 10 cm and a seed rate of 62.5 kg ha^{-1}. Land preparation involved one ploughing followed by harrowing and levelling. Fertilizers were applied at the rate of 40:80:25 kg N, P_2O_5, and K_2O ha^{-1} along with 12.5 kg $ZnSO_4$ ha^{-1} as basal application, while farmyard manure was incorporated at 6 t ha^{-1} before sowing. Seeds were inoculated with *Rhizobium* and phosphate-solubilizing bacteria prior to sowing. Moisture management included mulching with wheat straw at 5 t ha^{-1}, applied at 30 DAS in the mulched plots. Weed control was carried out using cycle weeders and hand weeding, while pest and disease management followed standard recommendations. Harvesting was done at physiological maturity when 80% of leaves turned yellow and pods turned brown.

Observations were recorded at different growth stages on soil temperature, soil moisture with Hydra go instrument and yield attributing character (pods per plant, seeds per pod, seed yield per plant, grain yield and haulm yield). The data collected were subjected to statistical analysis as per the procedure described by Gomez and Gomez (1984) [4] for factorial randomized block design. Significance of treatment effects was tested at the 5% probability level, and the critical difference (CD) was calculated where the F-test was significant.

Result

Table 1: Soil temperature (°C) and moisture in volumetric water content (VWC, %) of soybean root zone as influenced by sowing windows, sowing depths and moisture management practices at different growth stages

	Soil temperature (°C)			Soil moisture (VWC, %)		
Treatments	**30 DAS (°C)**	**60 DAS (°C)**	**90 DAS (°C)**	**30 DAS (%)**	**60 DAS (%)**	**90 DAS (%)**
Sowing windows (D)						
D_1: 10th July	25.10	24.80	24.50	22.41	22.68	22.95
D_2 :5th August	24.50	24.20	23.80	22.95	23.22	23.58
D_3: 9th September	23.80	23.40	22.80	23.58	23.94	24.48
S.Em ±	0.01	0.01	0.01	0.10	0.08	0.07
CD at 5%	0.02	0.02	0.02	0.30	0.25	0.20
Sowing depth (S)						
S_1: Sowing at 5cm depth	24.90	24.50	23.90	22.59	22.95	23.49
S_2: Sowing at 10cm depth	23.30	23.00	23.10	24.03	24.30	24.21
S.Em ±	0.01	0.01	0.01	0.10	0.08	0.07
CD at 5%	0.02	0.02	0.02	0.30	0.25	0.20
Moisture management practice (M)						
M_1:With mulch	27.20	26.60	26.00	20.52	21.06	21.61
M_2:Without mulch	22.10	22.20	22.00	25.11	25.02	25.20
S.Em ±	0.01	0.01	0.01	0.10	0.08	0.07
CD at 5%	0.02	0.02	0.02	0.30	0.25	0.20
Interactions (D X S X M)						
$D_1S_1M_1$	27.82	27.60	26.70	19.96	20.16	20.97
$D_1S_1M_2$	20.82	20.43	21.91	28.06	26.61	25.28
$D_1S_2M_1$	27.65	28.04	27.05	20.12	19.76	20.66
$D_1S_2M_2$	20.07	21.65	22.62	26.94	25.52	24.64
$D_2S_1M_1$	27.71	26.87	26.03	20.06	20.82	21.57
$D_2S_1M_2$	20.43	21.91	22.23	26.61	25.28	24.99
$D_2S_2M_1$	28.04	27.05	26.05	19.76	20.66	21.56
$D_2S_2M_2$	21.65	22.62	22.23	25.52	24.64	24.99
$D_3S_1M_1$	26.87	26.03	25.35	20.82	21.57	22.19
$D_3S_1M_2$	21.91	22.23	19.84	25.28	24.99	27.14
$D_3S_2M_1$	27.05	26.05	25.35	20.66	21.56	22.19
$D_3S_2M_2$	22.62	22.23	19.84	24.64	24.99	27.14
S.Em ±	0.02	0.02	0.03	0.20	0.15	0.10
CD at 5%	0.06	0.05	0.09	0.60	0.45	0.30

Soil temperature (°C)

At 30 DAS: Soil temperature varied significantly with sowing date, depth, and moisture management. Early sowing on July 10 recorded the highest temperature (25.10°C), followed by August 5 (24.50°C) and September 9 (23.80°C). Sowing at 5 cm depth (24.90°C) was warmer than 10 cm depth (24.30°C). Mulching increased temperature (27.20°C) compared to no mulch (22.00°C). The highest temperature was observed with July 10 sowing at 5 cm depth with mulch (27.60°C) and without mulch (22.40°C), while July 10 at 10 cm depth with mulch and later sowings recorded lower temperatures (Table 1).

At 60 DAS

Early sowing (July 10) recorded 24.80°C, followed by August 5 (24.20°C) and September 9 (23.40°C). Sowing at 5 cm depth (24.50°C) was higher than 10 cm (24.00°C). Mulching increased soil temperature (26.60°C) versus without mulch (21.90°C). Interactions showed July 10 at 5 cm with mulch had the highest temperature (27.20°C), while later sowings and deeper placements had lower values (Table 1).

At 90 DAS

Early sowing (July 10) again recorded the highest soil temperature (24.50°C), followed by August 5 (23.80°C) and September 9 (22.80°C). Sowing at 5 cm depth (23.90°C) was warmer than 10 cm (23.40°C), and mulching increased temperature (26.00°C) compared to no mulch (21.30°C). The maximum interaction effect was July 10 at 5 cm with mulch (26.80°C), (Table 1).

Soil moisture (VWC, %)

At 30 DAS

Soil moisture varied significantly with sowing date, depth, and moisture management. Early sowing on July 10 recorded 22.41%, followed by August 5 (22.95%) and September 9 (23.58%). Sowing at 5 cm depth had lower moisture (22.59%) than 10 cm depth (24.03%). Mulching reduced soil moisture (20.52%) compared to no mulch (25.11%). The lowest moisture was observed with July 10 at 5 cm with mulch (19.96%) and the highest without mulch (28.06%).(Table 1)

At 60 DAS

Early sowing (July 10) recorded 22.68%, followed by August 5 (23.22%) and September 9 (23.94%). Sowing at 5 cm depth had lower moisture (22.95%) than 10 cm (24.30%). Mulching reduced moisture (21.06%) versus without mulch (25.02%). Interactions showed July 10 at 5 cm with mulch had the lowest moisture (20.16%), and highest was without mulch (26.61%) (Table 1).

At 90 DAS

Early sowing (July 10) recorded 22.95%, followed by August 5 (23.58%) and September 9 (24.48%). Sowing at 5 cm depth had lower moisture (23.49%) than 10 cm (24.21%). Mulching reduced moisture (21.60%) compared to no mulch (25.20%). The lowest moisture was July 10 at 5 cm with mulch (20.97%) and highest without mulch (25.28%), (Table 1).

Table 2: No of pods per plant, seed yield per plant (g), seed yield (kg ha^{-1}) and haulm yield (kg ha^{-1}) as influenced by sowing windows, sowing depths and moisture management practices at different growth stages

Treatments	No. of Pods per Plant	Seed Yield per Plant (g)	Seed Yield (kg ha^{-1})	Haulm Yield (kg ha^{-1})
Sowing windows (D)				
D_1: 10th July	40.33	14.08	2199	2578
D_2 :5th August	26.75	11.99	1632	2134
D_3: 9th September	16.92	9.60	983	1421
S.Em ±	0.70	0.70	21	15
CD at 5%	1.50	1.50	60	40
Sowing depth (S)				
S_1: Sowing at 5cm depth	30.67	12.53	1742	2097
S_2: Sowing at 10cm depth	25.33	11.25	1468	1992
S.Em ±	0.50	0.10	20	18
CD at 5%	1.20	0.30	55	50
Moisture management practice (M)				
M_1:With mulch	29.17	12.21	1672	2072
M_2:Without mulch	26.83	11.57	1538	2017
S.Em ±	0.50	0.10	18	15
CD at 5%	1.20	0.30	50	40
Interactions (D X S X M)				
$D_1S_1M_1$	44.67	14.83	2413	2651
$D_1S_1M_2$	42.00	14.33	2268	2602
$D_1S_2M_1$	39.00	13.82	2128	2552
$D_1S_2M_2$	35.67	13.35	1987	2507
$D_2S_1M_1$	31.67	12.82	1844	2202
$D_2S_1M_2$	27.67	12.35	1702	2157
$D_2S_2M_1$	24.67	11.82	1561	2107
$D_2S_2M_2$	23.00	10.96	1421	2072
$D_3S_1M_1$	20.00	10.52	1185	1512
$D_3S_1M_2$	18.00	10.35	1039	1457
$D_3S_2M_1$	15.00	9.47	900	1407
$D_3S_2M_2$	13.58	8.07	808	1307
S.Em ±	0.70	0.10	61	33
CD at 5%	1.50	0.30	168	85

No. of Pods per Plant
The number of pods per plant varied significantly across treatments. Early sowing on July 10th (40.33) produced the highest pod number, followed by August 5th (26.75) and September 9th (16.92). Sowing at 5 cm depth (30.67) outperformed 10 cm depth (25.33). Mulching (29.17) also improved pod number over no mulch (26.83). The maximum pods were recorded in July 10th sowing at 5 cm depth with mulch (44.67).

Seed Yield per Plant (g)
Seed yield per plant was significantly influenced by treatments. July 10th sowing gave the highest yield (14.08 g), followed by August 5th (11.99 g) and September 9th (9.60 g). Sowing at 5 cm depth (12.53 g) and mulching (12.21 g) were superior to 10 cm depth (11.25 g) and no mulch (11.57 g). The highest seed yield per plant was with July 10th sowing at 5 cm depth with mulch (14.83 g).

Seed Yield (kg ha^{-1})
Seed yield was significantly affected by treatments. July 10th sowing (2199 kg ha^{-1}) was superior to August 5th (1632 kg ha^{-1}) and September 9th (983 kg ha^{-1}). Sowing at 5 cm depth (1742 kg ha^{-1}) and mulching (1672 kg ha^{-1}) outperformed 10 cm depth (1468 kg ha^{-1}) and no mulch (1538 kg ha^{-1}). The highest yield was obtained with July 10th sowing at 5 cm depth with mulch (2413 kg ha^{-1}).

Haulm Yield (kg ha^{-1})
Haulm yield also varied significantly. July 10th sowing (2578 kg ha^{-1}) produced the maximum, followed by August 5th (2134 kg ha^{-1}) and September 9th (1421 kg ha^{-1}). Sowing at 5 cm depth (2097 kg ha^{-1}) and mulching (2072 kg ha^{-1}) outperformed 10 cm depth (1992 kg ha^{-1}) and no mulch (2017 kg ha^{-1}). The maximum haulm yield was recorded with July 10th sowing at 5 cm depth with mulch (2651 kg ha^{-1}).

Discussion
Soil Temperature and Moisture (Table 1)
Soil temperature and moisture strongly influence soybean yield by affecting root growth, nutrient uptake, and pod development. In this study, early sowing on July 10 maintained higher soil temperature than August and September sowings, leading to better establishment and yield potential (Kumudini, 2002; Bastidas *et al.*, 2008) [1, 5]. Sowing at 5 cm depth favored quick germination through warmer soils, while 10 cm depth conserved more moisture, which supported later growth (Egli & Cornelius, 2009) [3]. Mulching increased soil temperature but reduced soil moisture, enhancing mineralization in cooler conditions (Lal, 1974) [6] but risking moisture stress during pod filling. Without mulch, higher moisture levels supported pod filling and seed development (Purcell & Specht, 2004) [7]. Interaction effects showed July 10 sowing at 5 cm with mulch produced maximum temperature but minimum moisture, whereas without mulch, moisture was higher. This balance between soil heat and water proved critical, as water stress during reproductive stages reduces pod retention and seed size (Sionit & Kramer, 1977) [8]. Overall, early sowing with proper depth and moisture management enhanced soybean yield, confirming that favorable soil conditions are key. Similar results were reported by Board & Hall (1984) [2], who noted that timely sowing improves canopy growth and light interception. Thus, optimizing sowing time and moisture management is essential for stabilizing soybean productivity under variable climates.

Yield parameters (Table 2)
Soybean yield components such as pod number, seed yield, and haulm yield were significantly influenced by sowing windows, depths, and moisture management practices. Early sowing on July 10th consistently produced the highest pods per plant (40.33), seed yield (2199 kg ha^{-1}), and haulm yield (2578 kg ha^{-1}), which can be attributed to favorable soil temperature and moisture that supported better vegetative growth and reproductive efficiency (Kumudini, 2002; Bastidas *et al.*, 2008) [1, 5]. Delayed sowing in September drastically reduced pod number (16.92) and yield (983 kg ha^{-1}), indicating the adverse effect of shortened growing season and lower soil temperature on reproductive success. Sowing at 5 cm depth improved pod formation (30.67), seed yield (1742 kg ha^{-1}), and haulm yield (2097 kg ha^{-1}) compared to 10 cm depth, as shallow placement favored quick germination and better early vigor (Egli & Cornelius, 2009) [3]. Similarly, mulching enhanced pod number (29.17), seed yield (1672 kg ha^{-1}), and haulm yield (2072 kg ha^{-1}) over no mulch, likely due to improved soil temperature and reduced weed competition (Lal, 1974) [6]. However, higher moisture conservation without mulch supported better pod filling under certain conditions (Purcell & Specht, 2004) [7]. The interaction revealed that July 10th sowing at 5 cm depth with mulch produced the maximum pod number (44.67), seed yield (2413 kg ha^{-1}), and haulm yield (2651 kg ha^{-1}). This indicates that the combination of optimum sowing window, shallow depth, and mulch created the most favorable environment for both vegetative and reproductive growth. Adequate moisture during reproductive stages is crucial, as stress reduces pod set and seed size (Sionit & Kramer, 1977) [8].
Overall, the results demonstrate that early sowing with proper depth and moisture management maximizes soybean productivity. These findings align with Board & Hall (1984) [2], who reported that timely sowing ensures greater canopy development and efficient resource utilization, thereby enhancing yield stability.

References

1. Bastidas AM, Setiyono TD, Dobermann A, Cassman KG, Elmore RW, Graef GL, Specht JE. Soybean sowing date: The vegetative, reproductive, and agronomic impacts. Crop Sci. 2008;48:727-740.
2. Board JE, Hall W. Premature flowering in soybean yield reductions at nonoptimal planting dates as influenced by temperature and photoperiod. Agron J. 1984;76:700-704.
3. Egli DB, Cornelius PL. A regional analysis of the response of soybean yield to planting date. Agron J. 2009;101:330-335.
4. Gomez KA, Gomez AA. Statistical procedures for agricultural research. 2nd ed. New York: John Wiley and Sons; 1984. 680 p.
5. Kumudini S. Trial by fire: Temperature stress and soybean yield. Field Crops Res. 2002;78:155-162.
6. Lal R. Soil temperature, soil moisture and maize yield from mulched and unmulched tropical soils. Plant Soil. 1974;40:129-143.
7. Purcell LC, Specht JE. Physiological traits associated with soybean yield improvement. In: Soybeans: Improvement, Production, and Uses. 3rd ed. Madison, WI: ASA, CSSA, SSSA; 2004.
8. Sionit N, Kramer PJ. Effect of water stress during different stages of growth of soybean. Agron J. 1977;69:274-278.