PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.4270

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RESEARCH ARTICLE

Impact of land configuration methods on growth parameters of soybean in summer rice fallows

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OPEN ACCESS

ARTICLE HISTORY
Received: 05 July 2024
Accepted: 03 October 2024
Available online
Version 1.0 : 05 December 2024

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
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CITE THIS ARTICLE
Sahoo C, Ameena M, Shalini PP, Susha VS, Ayisha R, Ankit, Shilpa, Sharma S, Verma A. Impact of land configuration methods on growth parameters of soybean in summer rice fallows. Plant Science Today (Early Access). https:/doi.org/10.14719/pst.4270

Abstract

A field experiment was performed to examine the impact of land configuration methods on various growth attributes of soybeans in summer rice fallows at the Instructional Farm, Vellayani. The experiment was conducted from February to May 2023 in a split plot design with three main plot treatments, *viz*., Broadbed and furrow (BBF) (l_1), Ridge and furrow (RAF) (l_2) and flatbed method (l_3), and six varieties, *viz*., JS 9305 (v_1), KDS 726 (v_2), JS 2069 (v_3), AISB 50 (v_4), JS 335 (v_5) and Basara (v_6) as subplot treatments, replicated four times. The growth attributes were significantly influenced by land configuration methods where BBF recorded taller plants (14.98, 29.31, 39.06, 45.83 cm), highest leaf count (2.57, 4.73, 9.30, 11.07), superior leaf area index (LAI) (0.502, 1.495, 2.077, 3.898) and higher nodule fresh weight (0.850 g). However, the variety JS 2069 recorded taller plants (15.55, 30.47, 40.38, 47.95, 52.66 cm), highest leaf count (0.78, 2.07, 4.03, 4.95, 6.22), higher number of branches per plant (and superior LAI (0.534, 1.810, 2.471, 4.284) at all growth stages. Among the varieties tested, AISB 50 produced a higher nodule count of 41.88 (on par with JS 2069) and the highest nodule fresh weight (0.863). The study identified the BBF method as the most effective land configuration method and JS 2069 as the most suitable variety for soybean cultivation in summer rice fallows of Kerala.

Keywords

broadbed and furrow; ridge and furrow; summer rice fallow; LAI; nodule

Introduction

Soybean is a numero uno oilseed crop in India, as well as in the world. With the introduction and inception of commercial cultivation in India the crop is being cultivated in around 11.8 m ha with a production of 13.5 mt as per the 2020-21 estimate (1). Soybean constitutes one of the largest sources of vegetable oil and animal protein feed in the world (2). Soybean boasts the highest protein content among all food crops, ranging from 40 to 42 percent and ranks second only to groundnut in oil content, with levels between 18 and 22 percent among food legumes. Additionally, soybeans serve as a vital protein source for human and animal consumption, as well as for aquaculture. It is also utilized in the production of biofuel. There exists a huge demand for soybeans as a protein source. In Kerala, efforts are being made to improve the production of pulse crops and one of the approaches adopted is cultivation in summer rice fallows. Short-duration, high-yielding soybean varieties are available that can be utilized for cultivation in the rice fallows utilizing the residual moisture. Soybeans can be sown in rice fallows from January to March. However, the prospects of soybean cultivation in the summer rice fallows are not yet explored. The suitability of the varieties needs to be identified for the existing agroecological conditions. Soybean is very sensitive to excess moisture and the crop is affected if water stagnates in the fields. For growing in rice fallows, the most suitable land configuration method also needs to be identified. In this background, the present study is proposed to assess the performance of soybean varieties under different land configurations in the rice fallows during the summer.

Materials and Methods

The field experiment was carried out in the summer rice fallows of the Instructional Farm, attached to the College of Agriculture in Vellayani, Kerala, India. The site is located in B block lying at 8°43′N latitude, 76°98′ E longitude and at an altitude of 20.0 meters above mean sea level. Before the start of the experiment, soil samples were drawn from a depth of 0-15 cm and a composite sample was made to analyse the mechanical composition and chemical properties. The soil of the experimental site was sandy clay loam in texture, classified as Oxisols, under the Vellayani series. The experiment was carried out during the summer of 2023 (February-May). The normal weekly statistics on meteorological parameters, *viz.*, mean maximum and minimum temperature, relative humidity, and rainfall received from the Department of Agricultural Meteorology, College of Agriculture, Vellayani, during the cropping season are furnished in Fig. 1. The mean maximum temperature

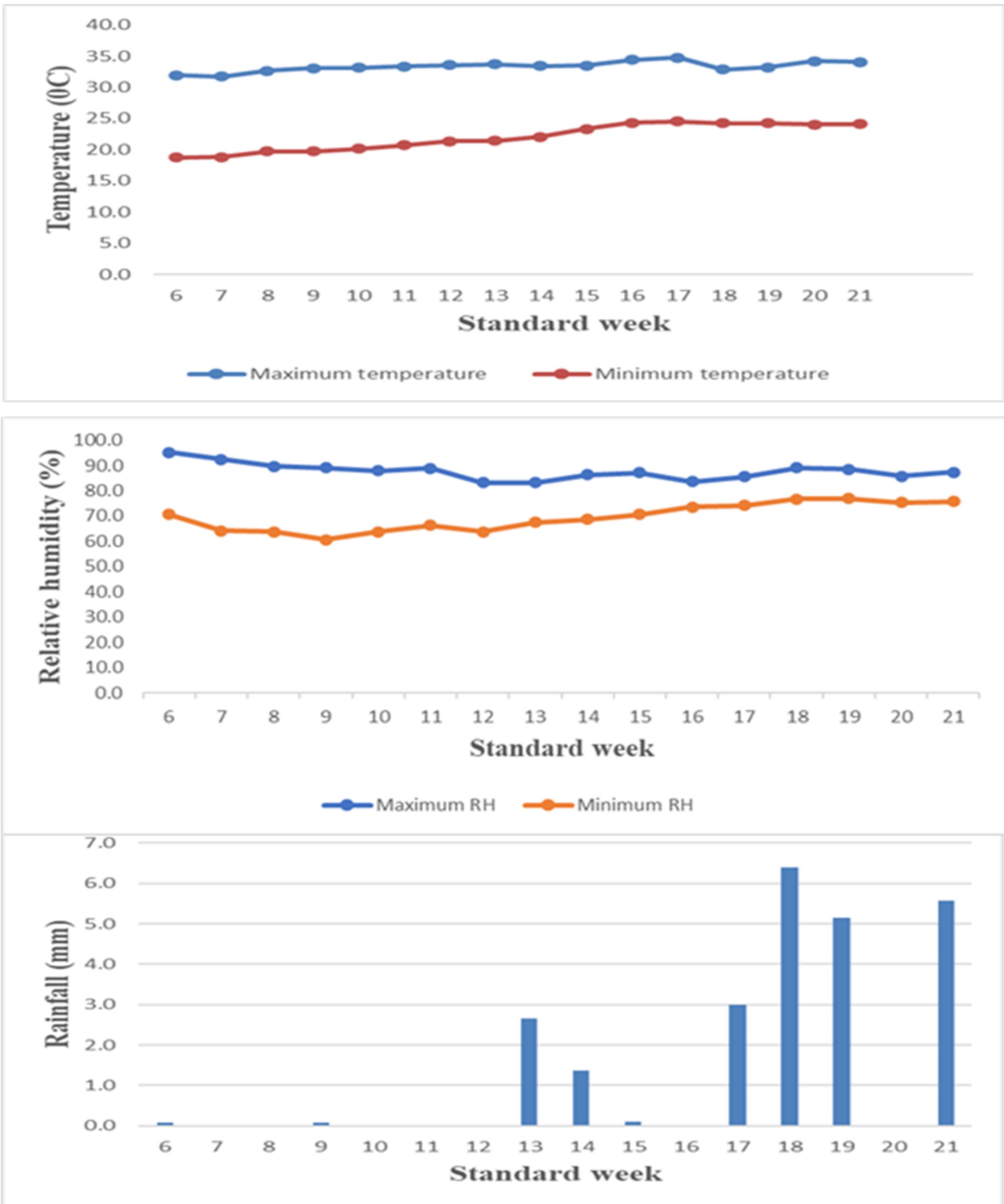

Fig. 1 Weather conditions during the experiment (February 2023 - May 2023).

ranged between 31.7 °C to 34.8 °C and the mean minimum temperature ranged between 18.8 °C to 24.5 °C, the mean maximum relative humidity ranged between 83.3 to 95.1 percent, and the mean minimum relative humidity ranged between 63.7 to 76.9 percent. The total annual rainfall received during the cropping season was 170.7 mm.

The field was plowed twice with a cultivator followed by a rotavator. Later the land was levelled, and the clods were broken. Three different land configurations, namely, Broadbed and furrow (BBF), Ridge and furrow (RAF) and flatbeds, were made. In the BBF method, raised beds were taken at a width of 120 cm with furrows of 15 cm width on both sides accommodating 3 rows in one bed. In the RAF method, the ridges were made at a width of 30 cm with furrows opened in between. In the flatbed system, the land was levelled without any furrows on the sides. Lime @ 250 kg ha^{-1} was spread equally and completely incorporated into the soil, followed by light irrigation. The seeds of six varieties were individually inoculated with Rhizobium culture 250 g ha^{-1} and shade-dried for 30 minutes. The treated seeds were sown in plots on February 10, 2023, with a spacing of 45 cm by 10 cm, followed by light irrigation. Growth attributes, including plant height, trifoliate leaf count per plant, number of branches per plant, and leaf area index (LAI), were measured at 15, 30, 45 and 60 days after sowing (DAS) and at harvest. The linear method was advocated for determining the leaf area, in which the length is multiplied by the greatest width of all the leaves. In observational plants, the length and breadth of fully opened and physiologically active leaves were measured.

Leaf area = K x L x B x N

K – 0.75 (constant for soybean) (3)

L – Length of leaf, cm

B – Breadth of leaf, cm

N – Number of leaves per plant

Then LAI was worked out based on the formula developed by (4),

$$\text{Leaf area index (LAI)} = \frac{\text{Leaf area of plant (cm}^2\text{)}}{\text{Land area occupied by the plant (cm}^2\text{)}}$$

Additionally, nodule count per plant and nodule fresh weight were recorded at 50% flowering. The experimental data obtained on various factors were statistically analyzed using analysis of variance (ANOVA) techniques for split-plot design. The GRAPES programme created by the Department of Agricultural Statistics, College of Agriculture, Vellayani, was used to compare treatments (5). The F test was used to determine significance (6). When the F test was significant, the critical difference (CD) was provided.

Results and Discussion

Plant height

The influence of land configuration on plant height was observed to be significant across all growth stages, as depicted in Table 1 and Fig. 2. Plants grown under the BBF (l_1) were taller at all the growth stages (14.98, 29.31, 39.06, 45.83 cm) except harvest and were comparable with the plants grown under the RAF method (14.30, 28.44, 39.09, 45.25 cm). However, at the final harvest, l_1 recorded the tallest plants (51.74 cm). Plants grown under the flatbed method recorded the shortest plants at all growth stages (12.52, 26.87, 36.92, 43.86, 47.65 cm).

There was considerable variability in plant height among the different varieties at every stage of growth, as interpreted in Table 1 and Fig. 3. The variety JS 2069 (v_3) produced taller plants with mean plant heights of (15.55, 30.47 cm) at 15 and 30 DAS and was on par with KDS 726 (v_2) (15.35, 29.76 cm) and Basara (v_6) (14.06, 29.06 cm). At 45 DAS, taller plants were observed in JS 2069 (40.38 cm) which was on par with KDS 726 (40.02 cm). At 60 DAS, the tallest plants were observed in JS 2069 (47.95 cm). This was followed by v_2, v_6, v_5, v_1, v_4. However, taller plants were seen at harvest in JS 2069 (52.66 cm), which was on par with KDS 726 (51.77 cm). At all the growth stages, the plant heights for the variety AISB 50 were the lowest (12.30, 25.60, 36.57, 42.46 and 45.94 cm).

These findings suggested that the BBF method and RAF method were favourable for promoting plant height, especially when compared to the flatbed method. This observation could be attributed to differences in soil aeration, moisture retention, or root development facilitated under BBF and RAF land configurations. Keteku *et al.* (2020)

Table 1. Effect of land configuration and varieties on plant height (cm) of soybean in summer rice fallows.

Treatments	Plant height (cm)				
Main plot - Land configuration (L)	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**At harvest**
Broadbed and furrow (l_1)	14.98	29.31	39.06	45.83	51.74
Ridge and furrow (l_2)	14.30	28.44	39.09	45.25	49.02
Flatbed (l_3)	12.52	26.87	36.92	43.86	47.65
SEm (±)	0.40	0.37	0.16	0.25	0.65
CD (0.05)	1.419	1.291	0.548	0.877	2.248
Sub plot - Varieties (V)					
v_1 (JS 9305)	12.78	26.32	36.71	43.39	47.37
v_2 (KDS 726)	15.35	29.76	40.02	47.05	51.77
v_3 (JS 2069)	15.55	30.47	40.38	47.95	52.66
v_4 (AISB 50)	12.30	25.60	36.57	42.46	45.94
v_5 (JS 335)	13.54	28.03	37.32	43.49	48.93
v_6 (Basara)	14.06	29.06	39.12	45.53	50.15
SEm (±)	0.54	0.79	0.26	0.26	0.72
CD (0.05)	1.546	2.257	0.739	0.742	2.046

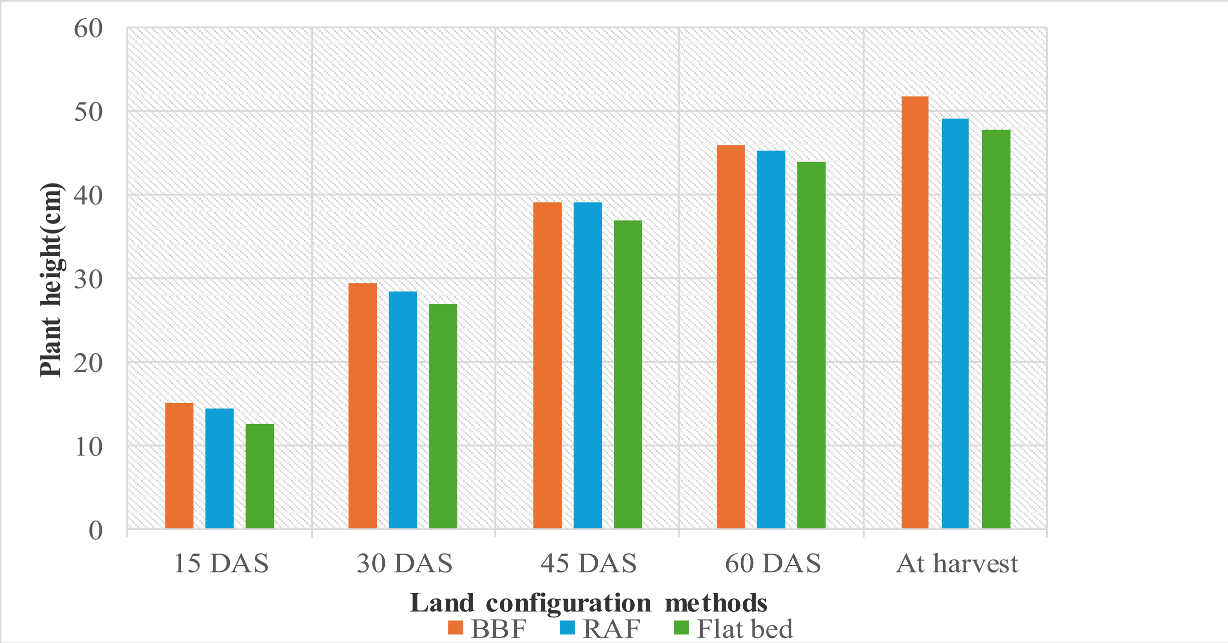

Fig. 2 Effect of land configuration methods on plant height of soybean in summer rice fallows.

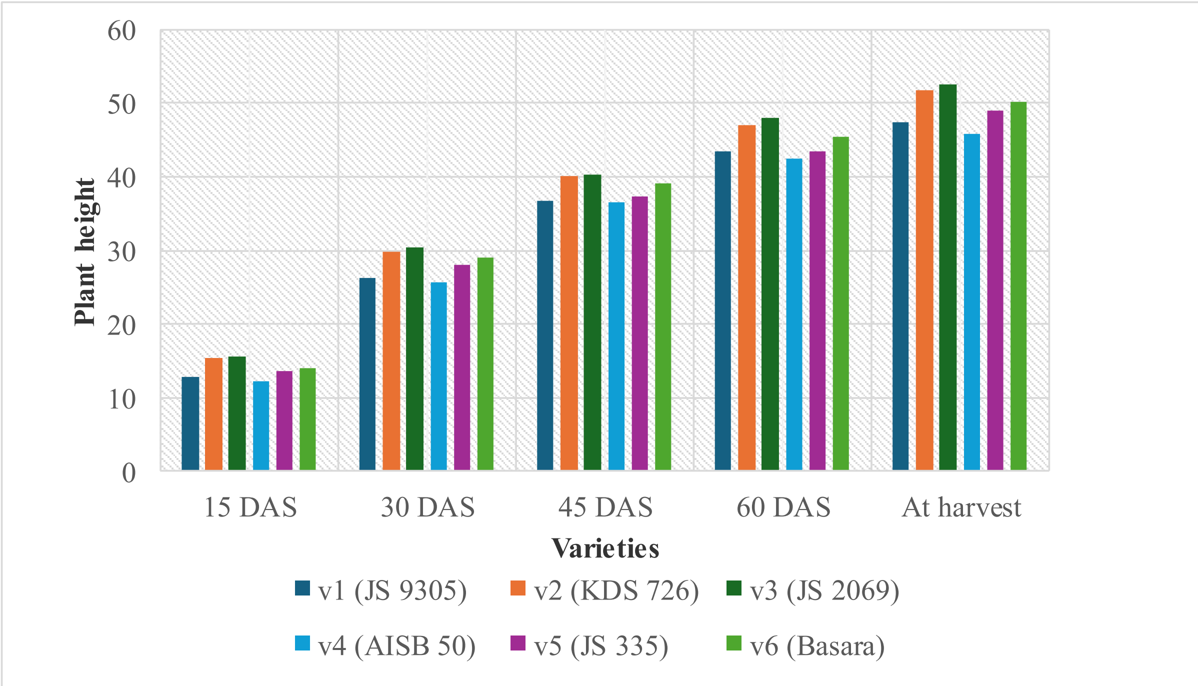

Fig. 3 Effect of varieties on plant height of soybean in summer rice fallows.

observed the tallest plants for the BBF method in soybeans during the rainy season, followed by the RAF and flatbed method (7).

Number of branches

The impact of land configuration on the number of branches was non-significant throughout all growth stages, except for 30 DAS and at the time of harvest, as indicated in Table 2. At 30 DAS, plants raised under the BBF (l_1) method produced a higher number of branches (1.89), followed by the RAF (1.71). At harvest, the number of branches recorded in both the broadbed and furrow method and the ridge and furrow method (5.66, 5.48) were comparable. However, the lowest number of branches was recorded for the flatbed method (4.90).

Considerable variation was observed among the different varieties regarding the number of branches per plant at all growth stages. The observations revealed that at 15 DAS and harvest, the variety JS 2069 (v_3) recorded a higher number of branches (0.78, 6.22) and was on par with KDS 726 (v_2) (0.72, 5.97). At 45 and 60 DAS, the results revealed that v_3 produced the highest branch numbers (4.03 and 4.95). However, JS 2069 recorded a higher number of branches (2.07) at 30 DAS and was on par with KDS 726 (v_2) and Basara (v_6). The AISB 50 variety exhibited the fewest branches per plant at every growth stage. The flatbed method recorded a lower number of branches compared to the other configurations, implying its unsuitability for branching. The highest number of branches per plant of soybean was observed in the BBF and RAF methods during Kharif by (8).

Table 2. Effect of land configuration and varieties on number of branches per plant of soybean in summer rice fallows.

Treatments	Number of branches per plant				
Main plot - Land configuration (L)	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**At harvest**
Broadbed and furrow (l_1)	0.72	1.89	3.73	4.73	5.66
Ridge and furrow (l_2)	0.57	1.71	3.45	4.53	5.48
Flatbed (l_3)	0.47	1.45	3.18	4.25	4.90
SEm (±)	0.07	0.03	0.13	0.13	0.08
CD (0.05)	NS	0.120	NS	NS	0.285
Sub plot - Varieties (V)					
v_1 (JS 9305)	0.46	1.43	3.00	4.28	5.20
v_2 (KDS 726)	0.72	1.92	3.80	4.70	5.97
v_3 (JS 2069)	0.78	2.07	4.03	4.95	6.22
v_4 (AISB 50)	0.32	1.28	2.83	3.98	4.25
v_5 (JS 335)	0.60	1.63	3.43	4.48	5.13
v_6 (Basara)	0.63	1.77	3.60	4.60	5.32
SEm (±)	0.09	0.14	0.14	0.15	0.22
CD (0.05)	0.247	0.395	0.406	0.413	0.619

Number of trifoliate leaf count

The influence of land configuration on the number of trifoliate leaves was significant at every growth stage as interpreted in Table 3. Plants grown under BBF (l_1) recorded the highest number of trifoliate leaves per plant at all the growth stages (2.57, 4.73, 9.30, 11.07, 5.32) followed by RAF (2.37, 4.40, 8.36, 10.18, 4.81) and flatbed method (2.26, 3.82, 7.14, 8.94, 4.05).

A perusal of the data revealed a significant influence of varieties on the number of trifoliate leaves per plant at all stages. The varieties KDS 726 (2.84, 4.8, 9.13, 11.17, 5.16) and JS 2069 (2.82, 4.83, 9.21, 11.27, 5.60) recorded a higher number of leaves per plant and were on par with each other at all the growth stages, followed by Basara, JS 335 and JS 9305. The variety AISB 50 produced the lowest number of leaves per plant at all the growth stages. These results indicated that the BBF method appears to create conditions more conducive to leaf development. This could be attributed to factors such as improved soil aeration, better water retention, or root system expansion afforded by this particular land configuration. The BBF method recorded the highest number of trifoliate leaves per plant in soybeans during the rainy season compared to the RAF and flatbed method, as reported by (7). Similar results have been reported by (9, 10, 11) for groundnut, black gram and summer groundnut, respectively.

Leaf area index (LAI)

The variations in LAI due to the land configuration were significant at all the growth stages, as shown in Table 4. Plants grown under the BBF method (l_1) recorded the highest LAI up to 45 DAS (0.502, 1.495, 2.077), followed by RAF (0.491, 1.394, 1.968) and flatbed method (0.455, 1.162, 1.733). However, the values were comparable at 60 DAS and harvest between l_1 (3.898, 3.579) and l_2 (3.809, 3.434). The lowest LAI was recorded in the flatbed method. The study revealed a notable impact of different varieties on the LAI across all growth stages. The JS 2069 variety demonstrated the highest LAI values (0.534, 1.810, 2.471, 4.284) at all stages except at 60 DAS. Following JS 2069, the varieties KDS 726, Basara, JS 335 and JS 9305 exhibited progressively lower LAI values. Conversely, the AISB 50 variety consistently recorded the lowest LAI values throughout all growth stages.

Table 3. Effect of land configuration and varieties on number of leaves per plant of soybean in summer rice fallows.

Treatments	Number of trifoliate leaf count				
Main plot – Land configuration (L)	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**At harvest**
Broadbed and furrow (l_1)	2.57	4.73	9.30	11.07	5.32
Ridge and furrow (l_2)	2.37	4.40	8.36	10.18	4.81
Flatbed (l_3)	2.26	3.82	7.14	8.94	4.05
SEm (±)	0.03	0.05	0.14	0.08	0.09
CD (0.05)	0.104	0.157	0.470	0.278	0.326
Sub plot - Varieties (V)					
v_1 (JS 9305)	2.04	3.84	7.77	9.27	4.02
v_2 (KDS 726)	2.84	4.80	9.13	11.17	5.16
v_3 (JS 2069)	2.82	4.83	9.21	11.27	5.60
v_4 (AISB 50)	1.89	3.80	7.19	8.66	3.80
v_5 (JS 335)	2.35	4.22	7.99	9.83	4.74
v_6 (Basara)	2.46	4.41	8.31	10.18	5.04
SEm (±)	0.05	0.06	0.12	0.09	0.20
CD (0.05)	0.144	0.182	0.337	0.266	0.578

Table 4. Effect of land configuration and varieties on LAI of soybean in summer rice fallows.

Treatments	LAI				
Main plot - Land configuration (L)	**15 DAS**	**30 DAS**	**45 DAS**	**60 DAS**	**At harvest**
Broadbed and furrow (l_1)	0.502	1.495	2.077	3.898	3.579
Ridge and furrow (l_2)	0.491	1.394	1.968	3.809	3.434
Flatbed (l_3)	0.455	1.162	1.733	3.417	3.056
SEm (±)	0.0021	0.022	0.019	0.039	0.053
CD (0.05)	0.0070	0.076	0.0670	0.1360	0.1850
Sub plot- Varieties (V)					
v_1 (JS 9305)	0.464	1.236	1.681	3.146	2.904
v_2 (KDS 726)	0.512	1.544	2.296	4.191	3.857
v_3 (JS 2069)	0.534	1.810	2.471	4.351	4.284
v_4 (AISB 50)	0.400	1.063	1.466	3.171	2.204
v_5 (JS 335)	0.484	1.194	1.749	3.504	3.224
v_6 (Basara)	0.502	1.252	1.893	3.884	3.664
SEm (±)	0.001	0.054	0.043	0.086	0.067
CD (0.05)	0.0034	0.1551	0.1225	0.2448	0.1905

These results suggested that land configuration can significantly influence LAI during the early growth stages of soybean, with the BBF method being particularly advantageous for enhancing canopy development. The comparable LAI between l_1 and l_2 at later stages implied that both methods are equally effective in maintaining canopy development as the crop matures. Similar results were confirmed by (12, 13, 14) in soybean, finger millet and green gram, respectively.

Number of nodules per plant

Table 5 depicts the results of the impact of land configuration methods and varieties on the number of nodules per plant. Upon careful examination of the data, it was noticed that there was no significant variation in the effect of land configuration on nodule number at 50 percent flowering. However, the number of nodules per plant varied significantly among the varieties. However, a significant variation was noticed among the varieties concerning the number of nodules at 50 percent flowering. The variety AISB 50 registered a higher number of nodules (41.88), which was comparable with JS 2069 (41.25), KDS 726 (40.52), and Basara (40). The variety JS 9305 exhibited the fewest nodules per plant, with an average of 35.78 nodules recorded. The highest number of root nodules per plant was recorded for the variety JS-335 (20.32) followed by RKS-18 (19.66), suggesting that certain genetic traits or characteristics inherent to different varieties may be limiting its nodulation potential (15).

Nodule fresh weight

The effect of land configuration on the nodule fresh weight was recorded to be significant at 50 percent flowering, as summarized in Table 5. Plants grown under the BBF method recorded a higher nodule fresh weight (0.850 g) and were on par with the RAF method (0.845 g). The lowest nodule fresh weight was observed in the flatbed method (0.806 g). Based on these findings, BBF and RAF methods are conducive to promoting optimal nodulation, possibly through improved soil aeration, root accessibility to nitrogen-fixing bacteria and moisture retention, all of which play critical roles in symbiotic nitrogen fixation.

The fresh weight of nodules at 50 percent flowering varied significantly between varieties. The AISB 50 variety recorded a higher nodule fresh weight (0.863 g) and was on par with v_3 (0.853 g), v_2 (0.843 g) and v_6 (0.835 g). The variety JS 9305 (0.792 g) recorded a lower nodule fresh weight and was on par with JS 335 (0.814 g). These results suggested that the BBF and RAF techniques promote optimum nodulation, possibly due to enhanced soil aeration, root accessibility to nitrogen-fixing bacteria, and moisture retention, all of which are important elements in symbiotic nitrogen fixation. Depending on the genetic trait governing nodulation, there may be variations in fresh nodule weight among varieties.

Table 4. Effect of land configuration and varieties on LAI of soybean in summer rice fallows.

Treatments	Number of nodules per plant	Nodule fresh weight (g)
Main plot - Land configuration (L)	**At 50 per cent flowering**	
Broadbed and furrow (l_1)	40.75	0.850
Ridge and furrow (l_2)	40.11	0.845
Flatbed (l_3)	38.51	0.806
SEm (±)	0.78	0.008
CD (0.05)	NS	0.0272
Sub plot - Varieties (V)		
v_1 (JS 9305)	35.78	0.792
v_2 (KDS 726)	40.52	0.843
v_3 (JS 2069)	41.25	0.853
v_4 (AISB 50)	41.88	0.863
v_5 (JS 335)	39.30	0.814
v_6 (Basara)	40.00	0.835
SEm (±)	0.73	0.014
CD (0.05)	2.070	0.0394

Conclusion

The study identified the BBF method as the most effective land configuration technique (taller plant, highest leaf count, superior LAI and higher nodule fresh weight) and JS 2069 as the best choice for soybean cultivation (taller plant, highest leaf count, superior LAI) in summer rice fallows, considering the growth parameters.

Acknowledgements

The authors express their deep gratitude to the Head of the Department of Agronomy and the Dean of the College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram, Kerala, India, for their invaluable financial support and technical guidance, which made the execution of this experiment possible.

Authors' contributions

CS, AM, SPP, SVS and AR performed the experiments. AM, SPP, SVS and AR designed the research. CS, AS, S, SS and AV wrote the manuscript. AS, S, SS and AV revised and corrected the manuscript. All authors have contributed to different sections of writing, reviewing, correction and statistical analysis. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare no conflict of interest.

Ethical issues: None

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