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Influence of Land Configuration, Seed Rates, and Variety on Physiology and Yield of Rainfed Soybean in Semi-Arid Tropics of Central India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The present experiment was conducted under the ongoing 'All India Coordinated Research Project' (AICRP) for Dry Land Agriculture at the College of Agriculture, Indore to study the effect of land configuration, seed rates, and variety on the physiology of soybean in Central India. The study was carried out with 3 main plot treatments (3 land configurations i.e. L1- Flat sowing-45 cm, L2- Raised bed of 90 cm with 3 Rows bed^{-1} and L3- Raised bed of 60 cm with 2 Rows bed^{-1}) and 4 subplot treatments (2 varieties of soybean i.e. V1-RVS 2001- 4 and V2-JS335; 2 seed rates i.e. S_1-60 kg ha^{-1} (75% of Normal seed rate) and S_2 40 kg ha^{-1}(50 % of Normal seed rate). The various observations related to physiological parameters viz., crop growth rate, relative growth rate, leaf area, leaf area index, and chlorophyll content were recorded. The seed yield of soybean at harvest was also recorded. The obtained data were analyzed by the method of variance and the null hypothesis was tested by the 'F' test. Further, the critical difference was worked out to judge the

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difference between the two treatment means. The results revealed that the land configuration, seed rates, and variety significantly influenced the physiological parameters in soybean which reflected in the seed yield of soybean.

Keywords: Soybean; land configuration; seed rate; crop growth rate; relative growth rate; chlorophyll content; leaf area index; RVS2001-4; JS-335.

1. INTRODUCTION

Soybean is an important cash crop in India. It is considered one of the main oil crops all over the world. The present status of soybean in India indicates the cultivation of crop over an area of 108.34 lakh ha with an annual production of 104.37 lakh MT and productivity of 979 kg ha^{-1} [1]. Madhya Pradesh is often called a 'Soybean State' or 'Fort of soybean' due to its contribution to the national basket to the extent of 52 percent of the area and 57 percent of production. It occupies a 55.46 lakh ha area with an annual production of 60.25 lakh MT and a productivity of 1086 kg ha^{-1} [1]. Soybean contains 20% oil of dry seed weight and is an important source of protein, which reaches 40% of dry seed weight along with calcium, iron, carotene, thiamine, and ascorbic acid. Soybean plants like many other legumes are capable of fixing and utilizing atmospheric nitrogen through a symbiotic relationship with *Rhizobium* bacteria at the root of the crops [2].

The flat-land cultivation system is more popular in the Malwa region at present for extensive cultivation of *Kharif* crop like soybean which faces the problem of water logging and poor aeration thereby affecting crop productivity adversely. The small change in land configuration in flat field conditions may help in improving the productivity of *Kharif* crops in Vertisols of the Malwa region. Using light machinery like bund former and *desi hal* with minor modifications may improve the physical conditions and drain ability. It is assumed that land treatments will help to improve the physical conditions, root development, and overall productivity in Vertisols [3]. Apart from soil-related properties, the seed rate played a crucial role in optimizing crop productivity. Overseed rate or overplant population is causing non-podding in the plant due to insects attack and resulting in excessive plant growth, shrinking seed size, and reduced crop productivity. Thus, a reduced seed rate may help in maintaining the optimum plant population. Considering these facts, the present field experiment was conducted to study the effect of land configuration, seed rates, and variety on physiological parameters in soybean in the semi-arid tropics of Central India.

2. MATERIALS AND METHODS

2.1 Experimental Site and Climate

The present study was conducted under the ongoing "All India Coordinated Research Project" (AICRP) for Dryland Agriculture at the College of Agriculture, Indore. Indore is situated in the agro-climatic zone in Western Madhya Pradesh at an altitude of 555.5 meters above mean sea level (MSL). It is located at latitude 22.43^{o}N and longitude 75.66^{o}E. The meteorological data during the crop growth period from the month of June to October 2015 is presented in Fig. 1. The total rainfall was 1174.1 mm received in 31 rainy days which was lower than normal rainfall. At 30 SMW the rainfall received was very high on three rainy days (152 mm). During the growth period 27 days dry spell, the maximum and minimum temperatures varied from 25.43°C and 34°C and from 21.14°C to 28.14°C, respectively. The relative humidity ranged between 79 % to 92 %.

2.2 Initial Characteristics of Experimental Soil

The soil of the experimental field has been grouped under medium black (*Vertisols*) belonging to the fine montmorillonite hypothermic family of typical chromosterts predominantly clay in texture (clay- 54.9%, silt- 34.0%, and sand-11.1%). The organic carbon content (0.40%) and available nitrogen (180 kgha^{-1}) were low. The available phosphorus (11.28 kg ha^{-1}) was medium and potash (540 kg ha^{-1}) was high. The soil pH was (7.70) slightly alkaline. Electrical conductivity (0.35 ds m^{-1}) of soil was normal.

2.3 The Experimental Procedures

The present experiment was carried out with 3 main plot treatments (3 land configurations i.e. L1- Flat sowing-45 cm, L2- Raised bed of 90 cm with 3 Rows bed^{-1} and L3- Raised bed of 60 cm with 2 Rows bed^{-1}) and 4 subplot treatments (2 varieties of soybean i.e. V1-RVS 2001-4 and V2-JS335; 2 seed rates i.e. S_1-60kg ha^{-1} (75% of

Normal seed rate) and S_2 40kg ha^{-1}(50 % of Normal seed rate)).

2.4 Field Operations and Agronomic Practices

To get a good tilth of soil for sowing, the field preparation was started with summer ploughing by tractor-drawn plough followed by cross harrowing. Finally harrowing was followed by planking to level the field the raised beds were made with the help of a tractor-drawn bed maker before sowing. The recommended dose of nutrients for soybean used was 20 kg N, 60 kg P_2O_5, and 20 kg K_2O ha^{-1}. Nitrogen and phosphorus were applied through Di-ammonium phosphate (DAP) and the remaining Nitrogen and phosphorus were applied by Urea and SSP while potash was applied using Muriate of potash (MOP) fertilizer. All fertilizers were applied as basal in the furrows made and mixed with soil before placing the seeds. For ensuring perfect germination, healthy and good-quality seeds were used. Seeds were treated with carbendazim @ 2 g kg^{-1} seeds and after that inoculated with Soybean *Rhizobium* culture @ 5 gkg^{-1} seeds at the time of sowing. Sowing of the crop was done on 24th June 2015. The seed rate of soybean was used as 60 kg ha^{-1} and 40 kg ha^{-1} as treatments. Sowing was done manually. After germination, thinning was done 15 days after sowing to maintain the optimum plant population of the crop. Similarly, hand weedings were carried out twice to keep the crop weed free. To protect the crop from insects pests like girdle beetle, stem fly caterpillars, blue beetle, etc. in soybean at early stage two time spray at 30 and 45 days growth stages of Triazophos 40 EC 600 ml ha^{-1} were done. The crop was harvested on 27th September 2015 after attaining maturity. After harvesting, the produce of each plot was tied in bundles properly labeled and it was allowed to dry in the field for 4-5 days. The production of individual plots was threshed separately and winnowed. The yield of the crop in kilograms obtained from each net plot was recorded.

2.5 Observations Recorded

Various observations related to physiological parameters viz., crop growth rate, relative growth rate, leaf area, leaf area index, and chlorophyll content were recorded following standard methods (Watson, 1952). Further, the soybean seed yield was also recorded. The CGR, RGR and LAI were calculated as follows:

Crop growth rate (CGR):

$$CGR = \frac{W_2 - W_1}{P(t_2 - t_1)}$$

Where,

P is ground area ($1m^2$);
CGR is Crop growth rate and
W_1 and W_2 are plant dry weight at time t_1 and t_2, respectively.

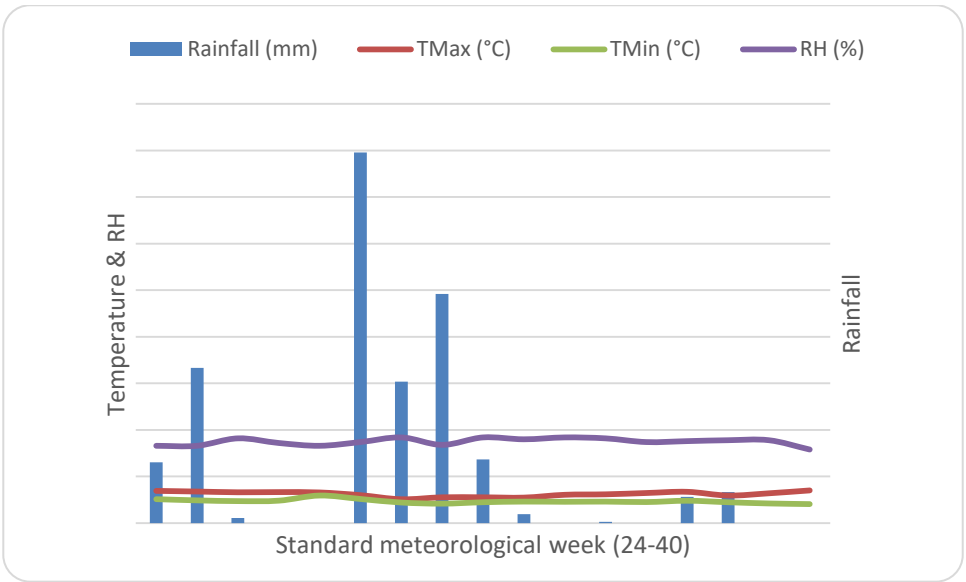

Fig. 1. Meteorological observations recorded during the crop period (June to October)

Relative growth rate (RGR):

$$RGR = \frac{Log_e\ W_2 - Log_e\ W_1}{t_2 - t_1}$$

Where,

RGR is Relative growth rate;
W_1 and W_2 are the dry weight (g) at time t_1 and t_2, respectively and
Log_e is natural Log.

Leaf area index (LAI):

$$LAI = \frac{\text{Leaf area } (cm^2)}{\text{Ground area (area covered in } cm^2 \text{ per plant)}}$$

2.6 Statistical Analysis

The obtained data were analyzed by the method of variance as described by Fisher (1995). The null hypothesis was tested by the 'F' test, which revealed the significance of the treatment effect. The critical difference (C.D.) of 5% was worked out to judge the difference between the two treatment means.

3. RESULTS

3.1 Crop Growth Rate (CGR)

The application of various land configurations, seed rates, and varieties showed a significant effect in improving the rate of crop growth at different stages (Table 1). The observations recorded at 30-45 and 45-60 DAS revealed that all treatments achieved a significantly superior crop growth rate as compared to the control. The maximum crop growth rate (14.45 g day^{-1} m^{-2}) at 30-45 DAS was recorded with the raised bed of 60 cm width followed by a raised bed of 90 cm width (13.98 g day^{-1} m^{-2}) and flat sowing at 45 cm inter-row spacing. The same trend was observed for other treatments. It was observed that 60 kg ha^{-1} seed rate significantly attained the maximum CGR at all the periods of crop growth. It was followed in the decreasing order by 40 kg ha^{-1} seed rate. In the variety RVS 2001-4 maximum crop growth rate (15.46 g day^{-1} m^{-2}) was observed as compared to the variety JS 335 (11.36 g day^{-1} m^{-2}).

3.2 Relative Growth Rate (RGR)

The mean relative growth rate under different treatments has been depicted in Table 2. In general, the RGR were decreased with the increase in crop growth stages. The RGR was found to be non-significant due to land configuration and seed rates. However, the variety RVS 2001-04 resulted higheer RGR than JS 335 variety at 30-45 DAS.

3.3 Leaf Area and Leaf Area Index (LAI)

The effect of various land configurations, seed rates, and varieties with respect to leaf area was found significant at both stages of crop growth (Table 3). The data revealed that the land configuration treatments significantly influenced the leaf area at both stages of crop growth. At before flowering stage, raised bed of 60 cm width with 2 rows bed^{-1} (797.49 cm^2) and raised bed of 90 cm width with 3 rows bed^{-1} (759.24 cm^2) were at par to each other recorded significantly higher leaf area over flat sowing method (633.47 cm^2) both the stages of crop growth. Leaf area (cm^2) was non-significant due to seed rates at 30 DAS and 60 DAS. Further, the data showed improvement in leaf area with the variety RVS 2001-4 over JS 335.

The observation on leaf area index recorded at before flowering and pod filling stage. It is evident from the Table 3 that there was a significant effect of different treatments on the leaf area index. At 30 DAS the maximum leaf area index was recorded in RB-60 cm (3.36) closely followed by RB-90 cm (3.19) and FS-45 cm (2.70). The LAI was found to be non-significant due to seed rates. In case of varieties RVS 2001-4 (3.25) was observed maximum LAI as compared to JS 335 (2.92). At 60 DAS the maximum leaf area index was recorded in RB-60 cm (10.48) closely followed by RB-90 cm (10.19) and FS-45 cm (9.52). The LAI was found to be non-significant due to seed rates and varieties.

3.4 Chlorophyll Content (SPAD)

The mean chlorophyll content under different treatments is presented in Table 4. The data revealed that the chlorophyll content in leaves at flowering stage of the soybean crop was significantly influenced by different treatments under study. In general, the chlorophyll content was highest in the treatment RB-60 cm (40.01) followed by RB-90 cm (39.46) and lowest in FS-45 cm (35.17). The chlorophyll content was found to be non-significant due to seed rates. In case of varieties, RVS 2001-4 (39.15) recorded

significantly higher chlorophyll content than JS- 335 (37.27).

Table 1. Effect of land configurations, seed rates, and varieties on Crop Growth Rate (CGR) in soybean

Factor	Treatment	CGR (g day^{-1} m^{-2})		
		30-45 DAS	45-60 DAS	60-75 DAS
Land configuration	L1: Flat sowing-45 cm	12.23	27.57	26.45
	L2: Raised bed of 90 cm with 3 Rows bed^{-1}	14.45	32.65	32.67
	L3: Raised bed of 60 cm with 2 Rows bed^{-1}	13.98	30.56	30.45
	S.Em (±)	0.12	0.18	0.56
	CD at 5 %	0.47	0.70	2.20
Seed rate	S1:75 % of normal Seed rate (60 kg ha^{-1})	14.24	31.52	30.32
	S2: 50 % of normal Seed rate (40 kg ha^{-1})	12.35	30.45	29.90
	S.Em (±)	0.17	0.32	0.43
	CD at 5 %	0.56	0.95	1.29
Variety	V1: RVS 2001-4	15.46	33.46	32.95
	V2: JS 335	11.36	27.90	26.73
	S.Em (±)	0.17	0.32	0.43
	CD at 5 %	0.56	0.95	1.29

Table 2. Effect of land configurations, seed rates, and varieties on relative growth rate in soybean

Factor	Treatment	RGR (g g^{-1} day^{-1})		
		30-45 DAS	45-60 DAS	60-75 DAS
Land configuration	L1: Flat sowing-45 cm	0.086	0.048	0.029
	L2: Raised bed of 90 cm with 3 Rows bed^{-1}	0.073	0.057	0.023
	L3: Raised bed of 60 cm with 2 Rows bed^{-1}	0.073	0.054	0.030
	S.Em (±)	0.005	0.005	0.001
	CD at 5 %	NS	NS	NS
Seed rate	S1: 75 % of normal Seed rate (60 kg ha^{-1})	0.076	0.054	0.028
	S2: 50 % of normal Seed rate (40 kg ha^{-1})	0.078	0.052	0.026
	S.Em (±)	0.003	0.002	0.001
	CD at 5 %	NS	NS	NS
Variety	V1: RVS 2001-4	0.072	0.056	0.024
	V2: JS 335	0.083	0.050	0.031
	S.Em (±)	0.003	0.002	0.001
	CD at 5 %	0.009	0.005	0.004

Table 3. Effect of land configurations, seed rates and varieties on leaf area index at 30 DAS and 60 DAS

Factor	Treatment	Leaf area (cm^2)		Leaf Area Index (LAI)	
		30 DAS	60 DAS	30 DAS	60 DAS
Land configuration	L1: Flat sowing-45 cm	633.47	2117.88	2.70	9.52
	L2: Raised bed of 90 cm with 3 Rows bed^{-1}	759.24	2305.73	3.19	10.19
	L3: Raised bed of 60 cm with 2 Rows bed^{-1}	797.49	2341.44	3.36	10.48
	S.Em (±)	25.6	38.0	0.09	0.17
	CD at 5 %	75.0	112,9	0.28	0.49
Seed rate	S1: 75 % of normal Seed rate (60 kg ha^{-1})	751.38	2260.61	3.24	9.87
	S2:50 % of normal Seed rate (40 kg ha^{-1})	708.76	2249.42	2.93	10.26
	S.Em (±)	16.6	49.0	0.11	0.25
	CD at 5 %	NS	NS	NS	NS
Variety	V1: RVS 2001-4	832.28	2353.77	3.25	10.31
	V2:JS 335	627.85	2156.27	2.92	9.82
	S.Em (±)	16.6	49.0	0.11	0.25

CD at 5 %	49.4	145.4	0.32	NS

Table 4. Effect of land configuration, seed rates and varieties on chlorophyll content and seed yield in soybean

Factor	Treatment	Chlorophyll (SPAD)	Seed yield (kg ha^{-1})
Land configuration	L1: Flat sowing-45 cm	35.17	332
	L2: Raised bed of 90 cm with 3 Rows bed^{-1}	39.46	418
	L3: Raised bed of 60 cm with 2 Rows bed^{-1}	40.01	526
	S.Em (±)	0.85	9.8
	CD at 5 %	2.54	29.0
Seed rate	S1: 75 % of normal Seed rate (60 kg ha^{-1})	38.97	462
	S2:50 % of normal Seed rate (40 kg ha^{-1})	37.46	389
	S.Em (±)	0.60	8.6
	CD at 5 %	NS	25.4
Variety	V1: RVS 2001-4	39.15	537
	V2: JS 335	37.27	313
	S.Em (±)	0.60	8.6
	CD at 5 %	1.70	25.4

3.5 Seed Yield

Among the land configuration treatments, RB-60 cm 2 rows bed^{-1} resulted in significantly higher grain yield (526 kg ha^{-1}) over other land configuration treatments (Table 3). The seed rate of 60 kg ha^{-1} (462 kg ha^{-1}) recorded a significantly higher grain yield than 40 kg ha^{-1} (389 kg ha^{-1}). Further, the variety RVS 2001-4 (537 kg ha^{-1}) recorded significantly higher grain yield than JS 335 (313 kg ha^{-1}).

4. DISCUSSION

Physiological parameters *viz.,* crop growth rate, relative growth rate, leaf area, leaf area index, and chlorophyll content were found significantly influenced by land configuration at all the crop growth stages. At the final stage of observation, raised bed of 60 cm and 90 cm width, gave statistically higher leaf area, leaf area index, and chlorophyll content and these were found significantly superior over flat sowing of 45 cm inter-row spacing but the leaf area in a raised bed of 60 cm width (2 rows bed^{-1}) and raised bed of 90 cm width (3 rows bed^{-1}) were found at par to each other at before flowering stage. CGR (Crop growth rate) at 45-60 DAS was the maximum. Among the land configuration treatments, all the improved techniques of land configuration recorded higher CGR over the conventional method of sowing at 45-60 DAS of the crop growth but at a later period of crop growth, raised bed of 60 cm width and raised bed of 90 cm width found equally effective and produced more CGR than flat sowing of 45 cm inter-row spacing at 30- 45 DAS. In the case of leaf area and leaf area index (LAI), raised bed-60 cm and raised bed-90 cm width being at par resulted in significantly higher leaf area and LAI per plant over flat sowing-45 cm inter-row spacing before the flowering stage due to light interception properly on leaf area and favorable environment condition. Khatri et al. [5] also reported that when wheat crop was grown on 3-row beds the growth parameters such as number of tillers per meter row length, leaf area index, crop growth rate, and dry matter accumulation, as well as yield attributes such as the number of grains earhead^{-1}, grain yield earhead^{-1} and test weight were the highest. Similar results with regards to higher physiological parameters in a raised bed of 60 cm width over a flat sowing method of 45 cm inter-row spacing. Many researchers *viz.* Hari et al. [6], Aher et al. [7], and Aher et al. [8] also reported similar findings. In physiological parameters only crop growth rate was significantly influenced by seed rates at most of the crop growth stages. The highest value of crop growth rate and relative growth rate was recorded with 60 kg seed rate ha $^{-1}$ in most of the cases due to an increase of dry matter accumulation (DMA) at various stages and photosynthesis rate. The achievement of the higher value of most of the growth parameters when 60 kg seed ha^{-1} was applied could be attributed to the reason that it was the most optimum rate at which the plants had the appropriate space and required nutrients to grow horizontally, whereas, as the seed rate increased there was more interplant competition. This was due to better soil aeration, a

developed deep root system, and better utilization of nutrients by crop. Lone et al. [9] and Vyas and Khandwe [10] also reported similar findings. The physiological parameter like crop growth rate (CGR), relative growth rate (RGR), leaf area (LA), leaf area index (LAI), and chlorophyll content were significantly influenced by varieties at most of the growth stages except the leaf area index at harvest. RVS 2001-04 produced more CGR, RGR, LA, LAI, and chlorophyll content than JS 335 variety probably due to its better performance in prevailing climatic conditions, soil water movement, and uptake of nutrients by plants at this location.

Raised bed system of 60 cm width (2 rows bed^{-1}) significantly increased the seed yield. The 37.47 % increase in seed yield was recorded in raised bed system of 60 cm width (2 rows bed^{-1}) against flat sowing of 45 cm inter-row spacing. Raised bed system of 90 cm width (3 rows bed^{-1}) also significantly increased the seed yield over flat sowing of 45 cm inter-row spacing. Superior yield with raised bed system of 60 cm width (2 rows bed^{-1}) and raised bed system of 90 cm width (3 rows bed^{-1}) as compared to sowing on flat sowing method of 45 cm inter-row spacing was mainly due to increased number of pods, number of seeds per pod, and grain weight per plant. Similar results of higher yields in altered land configuration over the flatbed method were also reported by Patel et al. [11], Lakpale and Tripathi [12]. The grain yield of soybean was significantly influenced by seed rates. A seed rate of 60 kg ha^{-1} resulted in a significantly higher grain yield (462 kg ha^{-1}) over a 40 kg ha^{-1} seed rate (389 kg ha^{-1}). Jasani et al. [13] reported that the increasing seed rate from 40 kg ha^{-1} to 70 kg ha^{-1} increased the seed yield of soybean significantly. The grain yield decreased from 462 kg ha^{-1} in 60 kg ha^{-1} to 389 kg ha^{-1} in 40 kg ha^{-1}. It is clear that sowing of the crop with a lower seed rate resulted in a conspicuous reduction in the number of pods $plant^{-1}$ and number of seeds pod^{-1} and grain weight $plant^{-1}$. The increases in grain yield due to optimum seed rate have also been reported by Patel and Varshney [14], Lone et al. [15], and Singh et al. [16]. Among the soybean varieties, RVS 2001-4 gave the grain yield higher than JS 335. Grain yield was positively related to plant height, primary and secondary branches, total dry matter, and number of pods per plant. Varieties play an important role in determining the yield of a crop. The potential yield of variety within its genetic limit is set by the environment. Islam *et al*. [17] also reported a significant genotypic difference with respect to morphological, physiological, and phonological characters and yield and yield components [18].

5. CONCLUSION

Thus, the study revealed that the land configuration, seed rate, and variety significantly influenced the physiological parameters of soybean crop which was reflected in terms of seed yield. Among the treatments tested, raised bed of 60 cm with 2 Rows bed^{-1} with 75 % of normal seed rate (60 kg ha-1forvariety RVS 2001-4 emerged as a viable technique for better physiology of soybean crop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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