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Suitable mechanization for increasing soybean (*Glycine max*) production under aberrated climatic regime of Madhya Pradesh

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ABSTRACT

As a result of climate change during the last decade, the normal rainfall pattern has been disturbed which resulted in frequent aberrations with extreme situation of sudden downpour or long dry spells resulting in severe stress on soybean [*Glycine max* (L.) Merr.] crop leading to yield reduction. The establishment of *in situ* rainwater management strategies is essential for minimizing risk of crop failure and stabilizing soybean production. Under such circumstances, KVK, Panna, introduced ridge and furrow equipment for the line sowing of soybean at KVK instructional farm during rainy (*kharif*) season 2014–17. The maximum yield was recorded in the plants sown in ridge and furrow technique (17.2 q/ha) followed by broad bed furrow technique and sweep seed drill (15.7 and 15.2q/ha, respectively) as compared to broadcasting methods of sowing (11.1 q/ha). The benefit:cost ratio was recorded as high as 1:2.9 under ridge and furrow technique of sowing followed by broad bed furrow technique and sweep seed drill (1:2.7) compared to broadcasting (1:2.0). The ridge and furrow equipment saved more soil moisture (13, 17, 20 and 23% respectively) at 5 days interval for 20 days through increased infiltration rate of rainfall and reduced runoff that lead to slow rate of soil erosion than broadcasting. The furrow allows drainage of excess water in case of heavy precipitation, while also allowing *in situ* moisture conservation during dry spells, thus mitigating the detrimental effects of excess and dry spell situation in soybean crop.

Keywords: B:C ratio, Moisture dynamic, Root nodule, Yield

Soybean [*Glycine max* (L.) Merr.] is one of the important economic crops grown throughout the world including India. It is considered as a good source of protein and edible oil. Apart from this, soybean has been a predominant component of monotony cropping system in Madhya Pradesh, India. Among the different districts of Madhya Pradesh, 15000 ha area of Panna (16.18%) is covered by rainy (*kharif*) season soybean. The average rainfall received annually in Panna is 1276 mm. However, the productivity of Panna district is as low as 11 q/ha against variety potential of 18–20 q/ha and the main reason of low productivity is climate change which took place during the last decade. As a consequence of climate change the rainfall pattern and distribution had exhibited frequent aberrations with extreme situation of sudden downpour or long dry spells causing severe stress on soybean crop and as a results steep reduction in the soybean yield was recorded (Dupare *et al*. 2020). Moreover, the climate change negatively affects the soybean ecosystems especially high temperature and erratic rainfall. The growth, development, yield, and quality of soybean are subject to all these changes of climatic conditions and any change in the soybean production under future climate scenario will affect the grain and edible oil security.

Further, the *in situ* rainwater management strategies are playing the important role in maintaining the moisture during the dry spell. However, the establishment of *in situ* water harvesting system is of great concern and is very limited. Keeping in view, the importance of *in situ* moisture conservation, KVK Panna (Madhya Pradesh) introduced ridge and furrow equipment for line sowing of soybean which minimized the risk of crop failure and helps stabilize the soybean production. This technology increased the yield and saved the soil moisture through increased infiltration rate of rainfall and simultaneously reduced the runoff which further slowed down the rate of soil erosion and furrow allow drainage of excess water in case of heavy precipitation thus mitigating the detrimental effects of excess and dry spell situation.

MATERIALS AND METHODS

The field experiment was conducted at KVK farm

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in Panna district of Madhya Pradesh during 2014–15 and 2016–17. Five sowing methods, viz. broadcasting, flat bed (45 cm), sweep seed drill (45 cm), broad bed furrow (135 cm wide, 4 rows per raised bed) and raised bed furrow (60 cm wide, 2 rows per raised bed) with seed rate of 75 kg/ha were laid out. The raised beds were formed after conventional tillage. The field experiments were carried out in randomized block design (RBD) with three replications.

The soybean crop (variety JS-9305) was sown on the agricultural farm during 20–25 June and harvested in mid-October. The recommended dose of fertilizers (20:60:20 N: P: K kg/ha) was applied as urea (46% N) and single superphosphate (16% P_20_5) and Murat of potash (58% K_2O) as a basal dressing at the time of sowing.

Observations and analysis: Germination percentage was calculated by using the formula given below at 20 days after sowing (DAS).

$$\text{Seed germination (\%)} = \frac{\text{Total number of seed germinated per square meter area}}{\text{Total number of seed sown per square meter area}} \times 100$$

Soil moisture loss was monitored every third day. To measure the soil moisture content, soil sample was collected from inside the ridge at a depth of 15 cm. The weight of oven dry soil was recorded and subtracted from the fresh weight to determine total soil moisture loss for that period of time. The water loss for each unit at each sample was divided by the weight of the saturated soil to obtain percent water loss.

The data on plant height and yield attributes was recorded at harvest. The observations on root properties was recorded at 45 DAS, however yield attributes, viz. number of pods/plant, number of grain/pod, test weight and total yield were recorded at time of harvest. The leaves of five selected plants were detached and sampled at 60 DAS after plant removal from the plot and spread on levelled lands and measured by meter tape to work out the total leaf area of five plants and it was used for calculating Leaf Area Index (LAI) as per the formula given by Wasten (1947).

$$\text{Leaf area index} = \frac{\text{Leaf area per plant (cm}^2\text{)}}{\text{Ground area occupied by each plant (cm}^2\text{)}}$$

The production efficiency (kg/ha/day) was calculated using the given formula.

$$\text{Production efficiency (kg/ha/day)} = \frac{\text{Seed yield (kg/ha)}}{\text{Duration of the crop (Days)}}$$

The gross return and benefit cost ratio (B: C ratio) were calculated by using prevailing prices of inputs and outputs.

Statistical analysis: The data were subjected to analysis of variance (ANOVA) using the Microsoft Excel Version 2007 (Microsoft office 2007).

RESULTS AND DISCUSSION

Plant population: The seed germination (%) has been shown in Table 1. Results revealed that the differences in the seedling emergence between different methods of sowing were highly significant. Soybean sown on ridges resulted in a greater germination percentage (77.3%), followed by BBF (72.7%), while seed broadcasting resulted in a lower emergence of seedlings (59.0%). The greater emergence of seedlings on ridge sowing was due to well pulverization of soil resulting in easier appearance of the seedling than flat sowing or broadcast method of seed sowing. A higher percentage of germination in ridge and furrow planter method was due to appropriate coverage of soybean seed in soil bed which allowed moisture and oxygen to approach the seeds under the covered soil and less distribution was justified and faster drying ridge and sensitivity seed oil (soybean) to high temperature and moisture was justified. However, normal planting resulted in 20–25% and 7–13% uncovered seeds in broadcasting and flat sowing, which normally do not aid seed to germinate. Similar results were reported by Billore *et al.* (2018).

Plant height: The average plant height of soybean crop was recorded at 60 DAS under different methods of planting (Table 1). Results revealed that significantly increased plant height was recorded in the soybean plants grown under ridge sowing (57.4 cm/plant) followed by broad bed furrow (56.3 cm/plant) at 60 DAS, while it was lowest in case of seed broadcasting (54.4 cm/plant). The above results demonstrate that ridge sowing displayed greater plant height as compared to broad bed furrow and broadcasting methods. The result of moisture content

Table 1 Effect of sowing methods on root and shoot parameter of soybean crop.

Treatment	Plant height (cm)	Root Length (cm)		No. of roots	Nodule number	Nodule diameter (mm)	Leaf area (cm^2)	LAI
		Main root	Lateral root					
BC	57.4	13.0	15.0	15.5	56.0	5.1	780	1.7
FS	56.3	13.6	15.9	18.5	58.1	5.1	870	1.9
SSD	56.0	14.6	17.5	18.6	60.5	5.5	900	2.0
BBF	54.6	16.2	18.6	19.4	60.0	6.0	900	2.0
RF	54.4	17.4	20.4	21.6	61.9	6.5	940	2.1
SEM	0.45	0.99	1.17	0.71	0.81	0.31	57.2	0.13
CV	1.41	11.5	12.07	7.09	2.37	10.4	11.2	11.8
CD (P=0.05)	1.48	3.2	3.8	2.3	2.6	1.1	186	0.43

BC, Broadcasting; FS, Flat sowing; SSD, Sweep Seed Drill; BBF, Broad bed furrow; RF, Ridge and furrow; LAI, Leaf Area Index.

showed that soil moisture content was conserved more in ridge plot as compared to other treatments. It was concluded that soil inverted by mouldboard plough plus disc harrow plus ridger was more suitable for the conservation of high soil moisture content. The reason may be that ridge plot had more water holding capacity due to highly loose soil particles. The present result is supported by the reports of earlier workers who demonstrated that in ridge tillage the moisture content was greater than the ploughed treatment (Billore *et al.* 2018).

Leaf area Index: The maximum Leaf area index at 60 DAS was recorded in the plants sown in ridge and furrow method (2.1 cm^2) followed by broad bed furrow method (2.0 cm^2) as compared to other sowing methods 1.7 and 1.9 cm^2 (Table 1). Prolonged period of moisture supply at different growth stages increased the leaf area of the crop enabling it to intercept most of the incoming photoradiation by photosynthetic organ and the conversion of the intercepted radiation into dry matter took place. It lead to more portioning of dry matter into economic grain yield and consequently the final maximum dry matter production was noted in this method (Lakpale and Tripathi 2012). Imbalanced availability of moisture during any growth stage decreased the production of biomass due to competition for moisture and significantly reduced profit than properly moisturized crop. Similar results were also reported by Billore *et al.* (2018).

Root growth: The results on main and associated lateral root length of soybean were recorded at 60 DAS (Table 1). It may be seen from the results that root development varied significantly between the treatments. Soybean sown on ridges resulted in increased main and associated lateral root length (15 and 18.4 cm/plant) followed by broad bed furrow (14.5 and 17.6 cm/plant), while flat sown and broadcasting resulted in lower root length (13.6 & 15.9 and 13 & 15 cm/plant, respectively). This may be because favourable conditions in soil structure were well preserved, ensured aeration and moisture. While reduced tap and associated lateral root length was due to compact soil structure under submerged situation. The submerged condition does not favour the proper establishment of the root below the soil surface. Shoot growth exhibited the symptoms of poor aeration, primarily seen as checked leaf expansion rates and sometimes a slight inhibition of photosynthesis. The nitrogen and carbon economy of plants was severely disrupted after flooding or moisture stress. Nitrogen uptake was impaired presumably through death of much of the existing root system and denitrification removing available nitrate form soil which lead to transient yellowing of leaves (Singh *et al.* 2015).

Nodule number and diameter: Ridge and furrow planting revealed its supersite in production of nodules (61.5 per plant) and their diameter at 60 DAS (6.5 mm/nodule) followed by broad bed planting with 4 rows (60/plant and 6.0 mm/nodule) and lowest recorded in flat planting and broadcasting 58 and 56 per plant, 5.0 mm/nodule of soybean. These planting methods are required not only to conserve

Table 2 Effect of sowing methods on yield attributes and economics of soybean crop

Treatment	Plant population	Percentage of emerge seeds	No. of total pods/ plant	No. of damage pods/plant	Percentage of damage pods	No. of grain filed pods/plant	No. of grains/ pods	Test weight (g)	Yield (q/ha)	Percentage increase	Production efficiency	Cost of cultivation (₹/ha)	Grass returns (₹/ha)	Net returns (₹/ha)	B:C ratio
BC	15	68.2	31	4.5	14.5	26.5	2.8	98	11.1	-	11.7	15646	33300	17654	2.0
FS	15.5	70.4	29.5	3.8	9.3	26.9	2.8	98	11.7	5.4	12.3	15846	35100	19254	2.2
SSD	16	72.7	36.3	3.9	10.7	32.4	3	98	15.2	36.9	16	16500	45600	29100	2.7
BBF	16	72.7	35.5	3.2	9	32.7	3	99	15.7	41.4	16.5	17500	47100	29600	2.7
RF	17	77.3	37.5	3	8.7	34.5	3.0	100	17.2	54.9	18.1	17755	51600	33845	2.9
SEM	1.19	1.2	1.3	0.07	1.3	1.1	0.15	0.63	0.57		0.42				
CV	12.9	3.0	6.9	3.5	22.1	6.2	9.3	1.11	6.9		4.8				
CD (P=0.05)	3.8	4.1	4.4	0.24	4.3	3.5	0.51	2.06	1.8		1.3				

BC, Broadcasting; FS, Flat sowing; SSD, Sweep Seed Drill; BBF, Broad bed furrow; RF, Ridge and furrow; LAI, Leaf Area Index.

moisture for plant growth but also to drain out excess water without causing erosion. In such aerobic surface soil, becomes strong sink for nitrogen and carbon and fibrous secondary roots develop which further help the *Rhizobia* to infect these roots and form nodule. There is also extensive growth of thin-walled aerenchyma tissue from lenticels on the surface of roots and nodules adding gaseous exchange and reducing the oxygen stress which resulted in increased nodule number and their diameter.

Yield attributes and yield: Results revealed that grain yield differed significantly between the treatments (P<1%) (Table 2). Soybean sown on ridges gave maximum grain yield 17,20 q/ha followed by broad bed furrow 1520 kg/ha, while flat sowing and seed broad casting gave minimum grain yield 11.70 and 11.1 q/ha, respectively. Similar result was also recorded by Asewar *et al.* (2019). The higher yield in altered land configuration, particularly in ridge and furrow system, can be accounted for the cumulative effect of yield and yield attributes like number of pods/plant (34.5) and number of grain/pod (3.0) and test weight (98 g) followed by broad bed furrow (32.3, 3.0, and 98 g, respectively) as compared to flat sowing and broadcast (26.9, 2.8, 98 g and 26.5, 2.8, 98 g, respectively). Similar results were also noted by Singh *et al*. (2012). The favourable growth responses may be accounted for reduced oxygen stress, better nutrient acquisition and favourable physical environment for crop growth and pod filling by making available the soil moisture for prolonged period of crop growth. The increased soil moisture availability was due to the increased infiltration rate of rainfall and reduced runoff. In such situations, furrow allows drainage of excess water in case of heavy precipitation, while it serves as *in situ* moisture conservation during dry spells thus mitigating the detrimental effects of excess and dry spell situation. These results are in confirmity with the findings of Singh *et al*. (2015).

Economic analysis: The results on economic analysis of various methods in soybean planting (Table 2) revealed that soybean sown on ridges, broad bed furrow with 4 row, flat sowing and seed broadcasting incurred ₹17755/ha, ₹17755/ha, ₹15846/ha and ₹15646/ha on total cost of production, respectively. Whereas total gross return was ₹51600/ha, from production of 1720 kg/ha, ₹47100/ha from production of 1520 kg/ha, ₹35100/ha from production of 1170 kg/ha and ₹33300/ha from production of 1110 kg/ha at the rate of ₹30/kg in case of ridges, broad bed furrow, flat sowing and broadcasting, respectively. Thus, ridge planting gave a high net return of ₹33845/ha, followed by broad bed furrow ₹29600/ha, flat sowing and seed broadcasting ₹19254 and ₹17654/ha, respectively. These results clearly demonstrate that soybean sown on ridge gave an additional income of ₹4245 against broad bed furrow, ₹14591 against flat sowing and ₹16191 against seed broadcasting on per hectare basis.

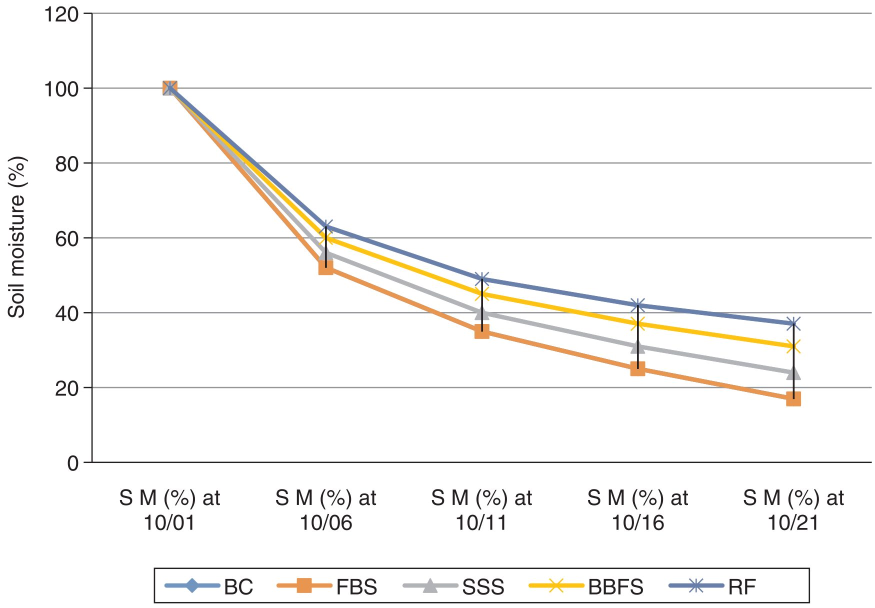

Fig 1 Available soil moisture at 5 days intervals in the month of October.

Available soil moisture dynamics: Among the different *in situ* soil moisture conservation techniques, furrow irrigated raised bed technique conserved 13%, 17%, 20% and 23% more soil moisture over broadcasting and flat sowing methods at 5 days intervals of soybean crop respectively (Fig 1). While 5%, 7%, 8%, and 9% more moisture conservation was seen under furrow irrigated raised bed sowing technique, respectively, than broad bed furrow irrigated sowing methods at 5 days intervals of soybean crop. Ridges and furrows treatment recorded higher soil moisture mainly due to greater infiltration by reduced runoff and subsequent arrest of the evaporation of the infiltrated water and reduced weed growth apparently contributes to soil moisture gain. Ridges and furrows have conserved the rainwater through reduced runoff loss, increased infiltration over traditional practice of moisture conservation (Lakpale and Tripathi 2012, Pradhan *et al.* 2013). Ridge and furrow technique recorded more soil moisture at each observation than traditional sowing methods because the rainfall could not be lost as runoff (Singh *et al*, 2015). The traditional sowing practice (broadcasting and flat sowing), the moisture conservation registered lower soil moisture during the cropping period mainly because of sealing of surface by rains that resulted in more runoff loss and less infiltration.

Ridge and furrow technology contributes in increased soybean yield and also helps in reducing cost of production. The results showed a convincing impact of ridge and furrow technique and economic superiority over conventional method of sowing. Ridge and furrow technology is very conducive in increasing the crop production and net income, its popularity would increase day by day among the farming community and area under such technologies is expected to enhance widely in Panna district of Madhya Pradesh. Suitable policies are needed in order to further facilitate promotion of Ridge and furrow technology by encouraging public-private sector cooperation and educating farmers about the use of this technology. The long-term impacts of this technology on food production, natural resources (land and water) conservation and linkages with poverty alleviation should be further explored. The participatory research at farmers' field could play pivotal role in technology improvement and dissemination.

Non-availability of ridge and furrow equipment and lack of knowledge to operate this equipment were the most important constraints. This equipment formed good type of ridges when field was ploughed by reversible mould bold plough. Besides these were also not available in adequate quantity to fulfill the farmers' need. As the cost was very high it was not possible to purchase this equipment by each and every farmer. These problems may be due to improper functioning of village level agriculture development agency, cooperative societies as well as poor coordination among line departments working in the area. Further, adequate credit facilities may be provided to the farmers at the village level for purchasing implements such as ridge and furrow which will b beneficial.

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