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Enhancement of Soybean (*Glycine max* L.) Productivity through Sowing Methods and Seed Rates in Telangana State

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ABSTRACT

Background: With the unparalleled growth in area and production, soybean has established itself as a leading oilseed crop of India. The crop is mainly grown under rainfed conditions, and the distribution of rainfall plays an important role in yield realization. The changed landform management with broad-bed furrow seed drill is gaining popularity as the system helps in *in situ* moisture conservation and draining out excess rainwater. A field experiment was conducted at Regional Sugarcane and Rice Research Station, Rudrur. The yield advantage by adoption of broad-bed and furrow (BBF) method over flat bed was 7.06%. Seed rate of 50 kg ha^{-1} recorded significantly higher mean seed yield of 2804 kg ha^{-1} over 75, 38, 20 kg ha^{-1}. The total benefit from adoption of BBF method recorded net returns of ₹ 53,233 ha^{-1} and B:C ratio of 2.58 over flatbed planting. Seed rate of 50 kg seed ha^{-1} recorded the highest net returns and B:C ratio this was followed by 75 kg ha^{-1} seed rate.

Methods: A field experiment was conducted for three years (2017-19) at Regional Sugarcane and Rice Research Station, Rudrur, situated at an altitude of 286.3 m above mean sea level at 18°49'41" N latitude and 78°56' 45" E longitude. Indeterminate variety of soybean ASB 22 was selected. The experimental plots (6m × 6m= 36 m^2) were laid out with split plot design with three replications. Main plot treatments were methods of planting: M_1- Flat bed, M_2- Broad bed and Furrow, and sub plot treatments were : seed rates; S_1- 75 kg ha^{-1} (30 × 10 cm), S_2- 50 kg ha^{-1} (30 × 15 cm), S_3- 38 kg ha^{-1} (30 × 20 cm), S_4- 20 kg ha^{-1} (30 × 30 cm).

Result: The grain yields, water productivity, harvest index and economics of soybeans under BBF method of planting (*in-situ* water conservation) and flatbed practices were studied. BBF method increased seasonal soil water storage by 5.37%, 5.78% and 6.20% respectively compared with flatbed planting for 2017, 2018 and 2019 respectively. Seed rate of 50 kg ha^{-1} recorded significantly higher mean seed yield of 2804 kg ha^{-1} over 75, 38, 20 kg ha^{-1}. The yield advantage by adopting seed rate of 50 kg ha^{-1} was 16.08%, 56.02% and 67.6% over 75, 38 and 20 kg ha^{-1} respectively. The total benefit from adoption of BBF method recorded net returns of ₹ 53,233 ha^{-1} and B:C ratio of 2.58 over flatbed planting. Seed rate of 50 kg ha^{-1} recorded the highest net returns and B:C ratio this was followed by 75 kg ha^{-1}. Broad bed and furrow method of planting and optimum seed rate in soybean will enhance the soybean productivity.

Key words: Broad-bed furrow, Harvest index, Soybean, Water conservation, Water productivity.

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is an important crop with high protein and oil content. It is also used to make soya milk, tofu, soy nuts, *etc.* During 2019, it was grown on an area of 12.5 m ha in India with a production of 9.0 million tonnes and productivity of 942 kg ha^{-1} (Anonymous, 2019). Furthermore, the furrow irrigated raised bed planting can save considerable amount of irrigation water and maximize water productivity (Bana *et al.,* 2013; Temesgen *et al.,* 2009). Also raised bed planting reduces seed rate and provides favourable environment for the growth and development of the soybean Kamara *et al.* (2014). The present investigation was therefore planned and conducted to study the growth, yield, economics and water productivity in soybean under different planting systems and different seed rates. Soybean have a smaller plant than most other grain crops and therefore have a smaller leaf area. A higher population is planted in order to intercept the maximum amount of sunlight. The ability of soybeans to branch out and produce more pods if there is enough space (phenotypic plasticity) explains the minor reaction of soybeans to different plant establishments (Khurshid *et al.,* 2006; McHugh *et al.,* 2017).

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At a high plant establishment soybean plants will branch little, grow straight up and bear pods high above the ground. With a decrease in plant population, the inner-row space plants increases and the plant produces more lateral branches and pods Muthamil selvan *et al.* (2006). With very low plant populations some of the lateral branches and pods will be borne close to the ground. Although yield is retained, some of the lateral branches will lodge and bear pods on the ground, which reduces the harvestable yield. Recommendations for soybean establishment differ considerably and are complex due to the variation with respect to row widths, tillage practices and planting date differences. In normal *kharif* plantings in June, maximum yields are obtained with 25 to 50 plants per square meter. Adjustments in plant population must be made on the basis of the interaction between the production potential of the field, phenotypic plasticity and lodging of the cultivar on the basis of the proposed planting date. With early plant dates cultivars that tend to lodge or produce more lateral branches can be planted in a lower population Kumar *et al.* (2014). This is not the case for a late planting date. Soybeans that are planted early in fields with a high potential tend to grow very lushly. In such a case the plant population can be reduced. The above points to final plant populations of 1,80,000 to 4,00,000 plants per hectare. The higher populations in narrower rows are a result of more space in the rows and the interplant competition being less, which reduces the risk of thin stems and lodging. Accurate plant densities must be based on seed quantities per hectare and not on seed mass. Seed is sold according to weight, which makes it difficult to calculate seed requirements. The labels on the seed package are supposed to indicate the number of seeds per kilogram. This can then be used as a basis for calculating the relative quantity of seeds required. Most planter tables that are used for calibration also use relative data and the plant population should then be regarded as estimated. The only way in which planters can be calibrated accurately is to count the number of seeds that are placed over a specific distance by the planter. The seed sizes of different cultivars vary considerably. They will probably vary between 5,000 and 8,000 seeds per kilogram. Some cultivars tend to produce bigger seeds more than others, but the influence of environmental conditions during the grain-filling period have the biggest effect. He *et al.* (2016) and Sarkar (2005) reported that if drought or any other stress factor is experienced during the grain-filling period, the seeds will be smaller than normal. A good blossom period that leads to a lot of pods can also result in smaller seeds. The reverse can also be true. Very small seeds will not have an effect on the yield of the crop, provided the germination of the seed occurs correctly. It is not uncommon to get a large variation in seed sizes in one production unit.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* session from 2017-2019 at Regional Sugarcane and Rice Research Station, Rudrur, situated at an altitude of 286.3. m above mean sea level (MSL) at 18°49’41" N latitude and 78°56’ 45" E longitude. The experimental site is in Northern Telangana agro-climatic zone of Telangana state, India and experiences semiarid climate. The long-term (2017-2019) temperature and precipitation data of the site, collected from weather station (RS&RRS, Rudrur, station), are illustrated in Table 1. The mean air temperature during the soybean growing season increased from 22.0°C in June to 28.4°C in October; the average temperature was 24.7°C. Both the maximum and minimum temperatures were greater in August than in the other months (Table 1). The solar radiation varied from 11.1 to 17.0 MJ m day over the crop period. The average relative humidity was 80.3%. Total 814.4 mm rainfall, with the maximum quantity in second fortnight of August and first fortnight of September (during flowering and development stages of soybean), occurred during the crop season. No irrigation was applied to the crop except during 2018, one irrigation was given in the month of July due to mid-season drought. The reference evapotranspiration (ETo) was 5.6 mm day that fluctuated with the varying air temperature and solar radiation. Indeterminate variety of soybean ASB 22, was planted on June 26 in 2017, June 27, during 2018 and June 15 in 2019. The experimental plots (6 m × 6 m= 36 m^2) were laid out with split plot design with three replications. Main plot treatments were methods of planting: M_1- Flat bed, M_2- Broad bed and Furrow, and sub plot treatments were : seed rates; S_1 - 75 kg ha^{-1} (30 x 10 cm), S_2 - 50 kg ha^{-1} (30 x 15 cm), S_3 - 38 kg ha^{-1} (30 x 20 cm), S_4 - 20 kg ha^{-1} (30 x 30 cm) . This resulted in a total of 24 plots in the field. Each of the plots was separated by 0.5 m of transition zone while each of the replications was demarcated by a buffer zone of 1 m in between. Broad bed and furrows were laid by tractor drawn broad bed and furrow former. Each broad bed was constructed with 120 cm width and 6 m length and 30 cm of furrow in between the broad beds which act as dead furrow used for storage of moisture.

Undisturbed soil samples were collected from the root zone of soybean: 0-10, 10 -20 and 20-30 cm soil proûle under each treatment by using core samplers. Texturally, the soil in the study site was heavy black soil in the 0-30 cm soil layer. The bulk density of the soil were determined by

Table 1: Weather data from 2017 to 2019.

Period	Rainfall (mm)	Temperature (°C) Max	Min	Mean	RH (%) Max	Min	Mean	ET° (mm day^{-1})
June	86.80	27.80	37.60	32.7	96.57	85.70	91.13	4.83
July	150.04	25.45	33.37	29.41	96.16	87.65	91.95	3.47
August	126.45	25.03	30.87	27.95	95.35	86.97	91.16	3.02
September	301.12	24.60	30.80	27.7	95.13	83.80	89.46	4.23
October	13.62	22.97	30.77	26.87	94.61	76.39	85.5	4.43

drying the samples in oven at 105°C for 24 h and recorded 1.02, 1.0, 0.98 for 2017, 2018 and 2019 respectively. Soil organic matter (OM) content was determined by ignition method in which weight loss of the soil samples on ignition was measured. The duration of the growth stages was determined using the procedures in Burton (1987). Plant heights were measured using a meter rule. SWS at vegetative (VE - V2) and reproductive stages namely: flowering (FL), pod initiation (PI), seed filling (SF) and maturity (MT) were determined by using Eq. (1) (He *et al.,* 2016; Liu *et al.,* 2013).

$$SWS=\sum\theta_{1/4} \text{ x } Zi_{1/4} \text{ x } n \qquad (1)$$

Where,
SW= total soil water storage (mm),
θ¼ moisture content for soil root zone,
Zi¼ soil layer (mm), n¼ number of soil layers.

Flowering and pod initiation lasted for 20 and 6 days, while seed filling and maturity took 32 and 18 days, respectively in 2017. The comparative length of the stages in 2018 and 19 were 16, 7, 37 and 18 days. The total SWS was determined for the upper 30 cm depth where more than 90% of the active roots were located (Li *et al.,* 2007) by adding the SWS from 0 to 10, 10-20 and 20-30 cm at the stated stage. After maturity on September 18th, 2017 at 117 days after planting (DAP), October 13th, 2018 at 120 DAP and October 13th, 2019 at 123 DAP. Plants within 36 m^2 at the central rows were harvested, threshed and grain yields per hectare were estimated. Above ground biomass at harvest time was taken from 30 m^2 (120 plants) from three replicates, oven dried at 70°C for 24 h and dry above ground biomass (DAB) per unit area was estimated. Harvest index (HI) was determined from the ratio of the harvested grain yield to DAB.

RESULTS AND DISCUSSION

Plant height (cm)

Plant height differed significantly between planting methods and seed rates. Broad bed and furrow method of planting recorded significantly superior plant height over flatbed method of planting in all three seasons. Among the seed rates, 50 kg ha^{-1} recorded significantly highest plant height over 75, 38 and 15 kg seed ha^{-1}. This might be due to in-situ conservation of moisture in furrows, proper aeration and optimum plant population with less inter and intra competition for light, nutrition and water led to highest plant height (Liu *et al.,* 2013, Li *et al.,* 2007). This was followed by 38 and 15 kg seed rate ha^{-1} on both BBF and flat bed. Lowest height recorded in with 75 kg seed ha^{-1}. Alliaume *et al.,* 2014 reported that higher seed rate leads to lanky vegetative growth in soy bean which resulted in higher infestation of defoliator at vegetative stage followed by pod blight at pod initiation stage Table 2.

Number of pods plant^{-1}

Broad bed and furrow method of planting recorded the highest number of pods per plant over flat bed method of sowing. Seed rate of 50 kg ha^{-1} recorded significantly higher number of pods per, plant which was followed by 38 kg ha^{-1}and was at par with 20 kg ha^{-1} (Table 2). Wang *et al.,* (2015) reported that optimum seed rate with critical requirement of soil moisture is necessary for production of higher pods.

Seed yield (kg ha^{-1})

Planting methods and seed rates significantly influenced seed yield however there was no interaction between the planting methods and seed rates. Broad bed furrow method recorded significantly superior seed yield over flatbed method of planting. The yield advantage by adoption of broad-bed and furrow (BBF) method over flatbed was 7.06%. Seed rate of 50 kg ha^{-1} recorded significantly higher mean seed yield of 2804 kg ha^{-1} over flat 75, 38, 20 kg seed ha^{-1} (Table 2.). The yield advantage by adopting 50 kg seed ha^{-1} was 16.08%, 56.02% and 67.6% over 75, 38 and 20 kg seed ha^{-1} respectively. Li *et al.,* 2001 reported that BBF system (on lands with slope less than 2%) in comparison to flatbed system induced good root development, good nodulation, better crop growth, better pod filling and early maturity in groundnut, besides considerable saving of time and cost of cultivation cost of cultivation. 20 kg seed rate per hectare recorded the lowest yield in both flat and broad bed method of planting.

Table 2: Effect of planting methods and seed rate on plant height, number of pods plant^{-1} and yield of soy bean.

Treatment	Plant height (cm)			Number of pods plant^{-1}			Seed yield (kg ha^{-1})		
	Flat bed	BBF	Mean	Flat bed	BBF	Mean	Flat bed	BBF	Mean
S_1 (75 kg ha^{-1})	48.88	46.13	47.50	101	118	109	2259	2448	2353
S_2 (50 kg ha^{-1})	49.56	51.62	50.59	136	176	156	2649	2959	2804
S_3 (38 kg ha^{-1})	49.05	48.88	48.96	119	128	129	1251	1214	1233
S_4 (20 kg ha^{-1})	49.09	48.88	48.98	129	143	132	868	943	905
	48.88	49.14		129	134		1757	1891	
	Planting method	Seed rate	Planting method X Seed rate	Planting method	Seed rate	Planting method X Seed rate	Planting method	Seed rate	Planting method X Seed rate
SEm (±)	0.04	0.24	NS	1.5	9.9	NS	18.49	71.28	NS
C.D. (p= 0.05)	0.27	0.76	NS	4.02	31.10	NS	121.2	222.1	NS

Table 3: Soil water consumption, water productivity and harvest index of soybean (mean from 2017-2019).

Treatments	Soil water consumption (mm)	Water productivity (kg ha^{-1} mm^{-1})	Harvest index (%)
Factor A (Soybean Planting Method)			
M_1 (Flat bed)	314.56	7.15	52.47
M_2 (Broad Bed Furrow (BBF))	456.23	8.06	58.98
SEm (±)	0.99	0.30	1.82
CD (p=0.05)	6.04	1.12	3.98
Factor B (Seed rate)			
S_1 (75 kg ha^{-1})	396.45	6.12	50.2
S_2 (50 kg ha^{-1})	404.23	7.95	56.42
S_3 (38 kg ha^{-1})	386.23	5.21	44.23
S_4 (20 kg ha^{-1})	398.56	4.40	41.67
SEm (±)	13.93	0.34	2.01
CD (p=0.05)	NS	1.62	5.62
Interaction (v x s)	NS	1.58	NS

Table 4: Economics of soybean planting methods as influenced by varied seed rate (mean from 2017-2019).

Treatments	Gross returns ₹ ha^{-1}	Cost of cultivation ₹ ha^{-1}	Net returns ₹ ha^{-1}	B:C ratio
Factor A (Soybean Planting Method)				
M_1 (Flat bed)	59,945	32,375	27,570	1.85
M_2 (Broad Bed Furrow (BBF)	66,841	30,366	36,475	2.20
SEm (±)	620.4	456.2	598.2	0.12
CD (p=0.05)	1969	1256	1563	0.26
Factor B (Seed rate)				
S_1 (75 kg ha^{-1})	86,106	35,671	50.435	2.41
S_2 (50 kg ha^{-1})	87,915	32,682	55,233	2.69
S_3 (38 kg ha^{-1})	44,034	29,512	14,522	1.49
S_4 (20 kg ha^{-1})	31,610	23,976	7,634	1.31
SEm (±)	662.3	432.5	562.3	0.09
CD (p=0.05)	1230	1162	1501	0.25
Interaction (v x s)	NS	NS	NS	NS

Soil water Consumption (mm)

The soil-moisture content in the soybean plots under the BBF method fluctuated with rainfall and air temperature over the growing season, with the flatbed method exhibiting a greater fluctuation of soil-moisture content. The soil moisture content was the maximum in July due to greater rainfall, but decreased in August due to limited rainfall and greater temperature and increased during the months of September and October in BBF method. The daily soil-moisture content at 5 cm depth was the maximum under BBF method and minimum in the flat bed method (Table 3).

Water productivity (kg ha^{-1} mm^{-1}) and harvest index (%)

Water productivity and harvest index were significantly the highest in broad bed and furrow method as it act as both water conservation channel and for draining of excess water (Table 3). 50 kg ha^{-1} seed rate recorded significantly the highest water productivity followed by 75 kg ha^{-1} seed rate. Adeboye *et al.* (2015); Qin *et al.* (2015) and Nuti *et al.* (2009) reported that broad bed and furrow registered high water productivity due to dead furrows in between rows.

Economics

Among planting methods, Broad bed and furrow method recorded the highest net returns and B:C ratio over flatbed method of planting. Seed rate of 50 kg ha^{-1} recorded the highest net returns and B:C ratio this was followed by 75 kg ha^{-1} seed rate (Table 4). Broad bed and furrow maker sow seed and apply fertilizer at same time which resulted in low cost of cultivation besides saving time (Sarkar and Singh 2006).

CONCLUSION

The grain yields, water productivity, harvest index and economics of soybeans under Broad-bed and furrow method of planting (*in-situ* water conservation) and the conventional practices were studied for three consecutive rainy seasons. broad-bed and furrow method of planting increased seasonal soil water storage by 5.37%, 5.78% and 6.20% respectively compared with conventional practice of planting without water conservation. The yield advantage by adoption of broad-bed and furrow (BBF) method over flat bed was 7.06%. Seed rate of 50 kg seed ha^{-1} recorded significantly higher mean seed yield of 2804 kg seed ha^{-1} over 75, 38, 20 kg seed ha^{-1}. The yield advantage by adopting 50 kg seed ha^{-1} was 16.08%, 56.02% and 67.6% over 75, 38 and 20 kg seed ha^{-1} respectively. The results analysis revealed that total benefit from adoption of BBF for the year 2017-2019 have been recorded net returns of ₹ 53,233 ha^{-1} and B:C ratio of 2.58 over flat bed of planting. Seed rate of 50 kg seed ha^{-1} recorded the highest net returns and B:C ratio this was followed by 75 kg ha^{-1} seed rate. Broad bed and furrow method of planting and optimum seed rate in soybean will enhance the soybean productivity.

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