Original Research Article

Influence of soybean (*Glycine max. L)* sowing methods and seed rate on nitrogen accumulation in soil

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ABSTRACT

The soybean (*Glycine max L.*) is a crop with a high demand for nitrogen (N). The root nodules that form in soybeans can fix atmospheric N effectively. To quantify available N in soil a field experiment was conducted at Regional Sugarcane and Rice Research Station, Rudrur to evaluate the impact of varying sowing methods and seed rates on yield of soybean and available N in soil after harvest of crop. Planting methods and seed rates significantly influenced seed yield and available nitrogen in soil. Broad Bed Furrow (BBF) method with seed rate 50 kg ha^{-1} recorded significantly higher number of pods per plant (105) and mean seed yield of 1891 kg ha^{-1} over flat bed with 50 kg seed rate ha^{-1} (1757 kg ha^{-1}) respectively. Broad Bed and Furrow method of planting recorded significantly higher live root nodules and available nitrogen in soil with 50 kg seed rate ha^{-1}. Seed rate of 75kg/ha recorded highest available N in soil on broad bed and furrow method. Broad Bed Furrow (BBF) method with seed rate 50 kg ha^{-1} recorded highest net returns (₹ 53,233 ha^{-1}) and highest B:C ratio (2.72) over flat bed of planting.

Keywords: Broad Bed and Furrow, Flat bed, Nitrogen, Root nodule, Soybean

1. INTRODUCTION

Soybean production is forecasted to grow by 55%, in contrast with the 100–110% expected demand increase by 2050 (1). Therefore, increasing overall productivity via implementation of best management technologies is a research priority from a food security goal. Furthermore, the furrow irrigated raised bed planting can save considerable amount of irrigation water and maximize water productivity and aeration to roots (2). Also raised bed planting reduces seed rate and provides favourable environment for the growth and development of the soybean (3). Soybeans 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 room (phenotypic plasticity) explains the minor reaction soybeans display to different plant establishments.

Nitrogen is one of the major nutrients that are required for soybean growth and development. Soybean plants obtain nitrogen from three sources [4], 1) nitrogen derived from biological N_2-fixation by root nodule, 2) nitrogen requirement of soybean can be met by soil nitrogen [5]. High levels of soil nitrogen inhibit symbiotic N_2-fixation, and under these conditions the soil supplies the majority of the plant's nitrogen needs [6]. Conversely, N_2-fixation supplies the majority of the plant's nitrogen requirements under conditions of low soil nitrogen, and 3) nitrogen from applied fertilizer. For optimum soybean yield, it is necessary to use both biological N2-fixation and nitrogen uptake by soybean roots [5, 6]. Nitrogen fertilizer applied to soybean is based on the plant nitrogen needs during seedling development prior to nodule formation that is crucial to the growth and development of soybean [5, 7]. [8] reported that N2-fixation began 14 days after planting only when soybean was cultivated under optimum temperature and moisture conditions, thus a small amount of nitrogen fertilizer at planting might be beneficial to early vegetative growth. It was pointed out that nitrogen applied before sowing was beneficial to soybean growth, given that soybean root nodules were not formed until at least 9 days after soybean emergence (9). Additionally, starter nitrogen fertilizer can supply nitrogen until biological N2-fixation begins by the root nodule [10].

2. MATERIAL 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 18^0 49'41" N latitude and 78^0 56' 45" E longitude. The experimental site is in Northern Telangana agro-climatic zone of Telangana state, India and experiences semiarid climate.

2.1. Weather Data

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.

Table 1: Weather data from 2017 to 2019

Period	Rainfall (mm)	Temperature (^{0}C)			RH (%)			ET_0 (mm day^{-1})
		Max	Min	Mean	Max	Min	Mean	
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

**RH: Relative Humidity; ET_0: Evapo Transpiration*

2.2 Agronomic Data

Broad bed and furrows were prepared with 120 cm of bed and 30 cm furrow. Asb 22 soybean late maturity variety inoculated on the day of planting with *Bradyrhizobium japonicum*. Indeterminate variety of soybean ASB 22, was planted on June 26 in 2017, June 27, during 2018 and June 15 in 2019 with a spacing of 30 x 10, 30 x15, 30 x 20 and 30 x 30 cm respectively. Starter fertilizer was not applied because of high soil test levels for P and K. Some minor hand-weeding was done in July month for additional weed control in three years of the study. Flowering and pod initiation lasted for 20 and 6 days, while seed filling and maturity took 32 and 18 days, respectively All plants in all plots were hand-harvested. The beginning of seed development (R5 stage), to determine plant density and biomass plant^{-1} (after drying the plants in a forced air drier at 60°C for 48 h). The pods were hand-threshed later, and all the seeds from the sample from each subplot were counted and then weighed. From these data we calculated seeds pod^{-1}, and seed yield (kg). Lodging was evaluated in each subplot at harvest, but minimal lodging was observed so not reported. The gross returns, cost of cultivation, net returns and benefit: cost ratio (B: C ratio) were calculated by using prevailing prices of inputs and outputs.

2.3 Experimental Design

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.

2.4 Soil Sampling

Initial soil samples were collected from each plot before sowing of crop. Undisturbed soil samples were collected from the root zone of soybean: 0–10,10–20 and 20–30 cm soil profile 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 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 collected soil samples were analysed for pH, EC and available K (11), available N (12) and P (13). Initial soil status was N @ 181.2 kg/ha, P_2O_5 @ 56 kg/ha; K_2O @ 320 kg/ha; Zn @ 0.25 ppm, Fe @ 4.00 ppm was recorded.

2.5 Statistical Analysis

The standard error of means (SEm ±) and least significant difference (LSD) at 5% probability (p=0.05) were used to compare the treatments and draw valid conclusions.

3. RESULTS AND DISCUSSION

3.1 Plant density (m^{-2})

Plant density at maturity stage recorded that seed rate of 75 kg ha^{-1} recorded significantly highest plant density m^{-2} in flat bed and was statistically at par with broad bed and furrow method of planting this was followed by seed rate of 50 kg ha^{-1} in both methods of planting. Final plant densities, as expected, had a linear response to seeding rate with sowing methods (14). Lowest plant density was observed in seed rate of 20 kg ha^{-1} followed by seed rate of 38 kg ha^{-1}. The two lower seeding rates had negligible plant mortality, whereas the two higher seeding rates had about 7% plant mortality. There is no interaction between the sowing methods and seed rates (Table 2).

3.2 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). (15) reported that optimum seed rate with critical requirement of soil moisture is necessary for production of higher pods.

3.3 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. (16) 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 density, number of pods plant^{-1} and yield of soy bean

Treatment	Plant density (m^{-2})			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})	33.33	32.13	32.73	101	118	109	2259	2448	2353
S_2 (50 kg ha^{-1})	22.16	21.62	21.89	136	176	156	2649	2959	2804
S_3 (38 kg ha^{-1})	16.05	14.88	15.46	119	128	129	1251	1214	1233
S_4 (20 kg ha^{-1})	11.09	10.18	10.63	129	143	132	868	943	905
	20.66	19.70		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
S.E.m (±)	0.04	0.24	NS	1.5	9.9	NS	18.49	71.28	NS
C.D. (p= 0.05)	0.27	0.76	0.98	4.02	31.10	NS	121.2	222.1	NS

**BBF:Broad Bed and Furrow*

3.4 Soil Available Nitrogen

Three year available nitrogen in soil initial and after harvest was analyzed. The initial soil status of N was 181.2 kg/ha. All treatments recorded higher available nitrogen than initial available nitrogen in soil after harvest of crop. During the year 2017, there is no significant variation among the planning methods in available N content in soil. However the percent increase from initial soil status was 7.45. During years 2018 and 2019 broad bed and furrow method recorded significantly higher available N in soil. The total N accumulation increases with plant density to a extent in soil (17).

The percent increase in available N is 15.23 and 18.37 respectively. Among seed rates, in three consecutive seasons, seed rate of 75 kg/ha recorded significantly higher available N in soil and was statistically at par with 50 kg/ha. The lowest available N was low in wider plant densities viz., 38 kg/ha and 20 kg/ha. The percent increase in available nitrogen during 2017, 2018 and 2019 is 12.0, 18.10 and 20.03 respectively.

Table 3: Available N in soil (from 2017-2019)

Treatments	**Available N (kg ha^{-1})**		
	2017	**2018**	**2019**

Factor A (Soybean Planting Method)			
M_1 (Flat bed)	194.7	200.4	202.7
M_2 (Broad Bed Furrow (BBF))	194.1	208.8	214.5
S.E.m (±)	2.17	1.18	1.3
CD (p=0.05)	NS	7.8	8.8
Factor B (Seed rate)			
S_1 (75 kg ha^{-1})	203.0	214	217.5
S_2 (50 kg ha^{-1})	202.0	211.3	214.5
S_3 (38 kg ha^{-1})	186.2	195.8	199.0
S_4 (20 kg ha^{-1})	186.5	197.3	202.8
S.E.m (±)	2.29	2.08	2.35
CD (p=0.05)	7.12	6.47	7.32
Interaction (v x s)	NS	NS	NS

**B:C ration: Benefit Cost ratio*

3.5 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 (18).

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
S.E.m (±)	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

**B:C ration: Benefit Cost ratio*

4. CONCLUSION

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. Available soil N was increased in broad bed and furrow method with seed rate of 50 k/ha.

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