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Effect of planting density and improved seeding machinery on yield and economics of soybean (*Glycine max*)

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 1997–98 to 2000–2001 in farmers' fields at Bhopal on clayey loam medium deep Vertisols, to study the effect of planting densities and improved seeding machines on growth, yield and economics in soybean [*Glycine max* (L.) Merr.]. The use of improved seeding machines such as seed-cum-fertilizer drill and strip-till seed-cum-fertilizer drill reduced the cost of operation by Rs 935 and Rs 1,578/ha and increased the net income by Rs 2,589 and Rs 3,703/ha, respectively, over the local seed drills used by the farmers. The planting density of 888,000 plants/achieved by the farmers through sowing at 22.5 cm by use of local seed drill mixing seed and fertilizer together increased the plant height and total dry matter disproportionally, thereby increasing the incidence of pests (32%) and decreasing the branching, filled pods, test weight of seeds and seed yield. Planting density of 440,000/ha increased the seed yield by 61.6% and the net returns by Rs 6,669/ha over farmers' practice. The planting densities at 666,000/ha and 533,000/ha produced the intermediate effects.

Key words : Soybean, Planting density, Seed-cum fertilizer drill, Strip till drill

Soybean is the main crop of Madhya Pradesh but the average productivity is only 1,089 kg/ha. One of the most important reason, for low productivity is adoption of very high plant population by the farmers (0.8–1.0 million/ha). This results in high biomass production per unit area exhausting most of the soil resources such as moisture and nutrients in the early stage of crop growth itself, thereby causing their deficit during the reproduction stage. It also causes hindrance to the infiltration of solar radiation. High plant population also results in high incidence of the pests such as stem fly, girdle beetle, semiloopers, pod borers and other leaf-eating pests. The intermittent rains during sowing also makes the farmers to complete the sowing quickly with the available resources.

The main reasons behind adoption of high plant population by the farmers was the use of local seed-drill which have fixed row spacings of 22.5 cm. Sowing is done by mixing seed and fertilizer. Use of improved seed-cum-fertilizer drill with adjustable row spacing aimed at placing the seed and fertilizer at a proper depth would therefore enable to optimize the plant population. Use of strip till seed-cum-fertilizer drill further enables the farmer to prepare their land and sow the crop in time at desired depth and row spacing in a single operation, thereby fully utilizing the time gap between the 2 rainy periods for sowing. The experiment was therefore conducted at the farmers' fields with the objecties of optimizing the plant population through use of proper planting density by adjusting row spacing and using improved seeding devices.

MATERIALS AND METHODS

The study was conducted for 4 years from 1997–98 to 2000–2001 under rainfed medium vertisols with silty-clay-loam texture at the Central Institute of Agricultural Engineering, Bhopal. The soils were poor in organic carbon content (0.3 to 0.4%) and available N (140–155 kg/ha), medium in available P (8 to 10 kg/ha) and rich in available K (190 to 230 kg/ha). The total precipitation received during the experimental period (June–September) was 822, 933, 1123 and 694 mm respectively with 19 and 12 rainy days/month during July and August. The treatments consisted of 3 seeding machinery as main plot treatments, viz. local seed drill, improved seed-cum-fertilizer drill and strip till seed-cum-fertilizer drill. Four planting densities of 888,000; 666,000; 533,000 and 444,000/ha with the row spacing at 22.5, 30, 37.5 and 45 cm were taken as sub-plot treatments. The 12 treatments combinations were taken in split plot design. The treatments were replicated 5 times in each year in 5 farmer's fields selected in a compact block in village Mugalia hat. The sub-plots were of the size of 50 m × 10 m.

In tractor operated local seed-drill (farmers' practice) distance between rows is generally fixed at 22.5 cm and have only 1 box. Seeds and fertilizers are mixed together at the time of sowing. The depth of application is also fixed. Improved seed-cum-fertilizer drill have an arrangement for adjustment of row spacings, 2 separate boxes for seed and fertilizer and separate metering devices with fluted rollers for seed and gravity type adjustable orifices and agitators for fertilizers for variable depth of placement and seed rate. In strip till seed-cum-fertilizer drill, a strip-till attachment of rotory blade (with 6 blades) for minimum soil manipulation and running ahead of the normal furrow openers, is available in addition to the seed and fertilizer metering arrangements.

The tillage for field preparations were common for the local seed-drill and seed-cum-fertilizer drill treatment, whereas 1 harrowing was required before the strip till drill operation.

Soybean cv 'JS 335' was sown as per the treatments using different seed drill. The plant-to-plant spacing was kept constant at 5 cm. The fertilizers were applied to the crop at recommended rate of 20:60:30 kg N:P:K + 20 kg S + 10 kg Zn/ha at the time of sowing. All the other crop management practices were also common for all the treatments.

The pests like girdle beetle, stemfly, semiloopers, tobacco caterpillers and pod borer were identified. The intensity of the pests was recorded by counting number of insects/m² of the cropped area at different stages of crop growth. On the basis of ETL of 4-5 girdle beetles or semiloopers/m², the pest control measures were adviced to the farmers. Generally, each farmer gave a spray of chlorpyriphos (20 EC) @ 1.5 litres/ha at 15 to 20 days after sowing + 1 spray of trizophos (40 EC) @ 1 litre/ha at 30-35 days after sowing and 1 spray of methomil (40 SP)@ 1 kg/ha at flowering stage. The above sprays took care of all the pests.

Various biometrical observations, viz. dry matter, plant height, branching, and yield attributes, viz. number of filled and unfilled pods, number of seeds/pod and seed yield/plant, were recorded on the basis of samples of 10 plants/replication (farmer). The seed yield data were recorded from the total plot yields of each of the farmer. The observation on 1,000-seed weight was recorded from the samples of plot yields.

Germination percentage of the crop in the field was recorded by separately marking out the area in the field under each treatment and sowing the counted seeds/m running length of the machine. For economical study, time required for land preparation and sowing, amount of seed required and cost of seed in each treatment were recorded separately.

RESULTS AND DISCUSSION

Relative performance of seeding machinery

The improved seeding machinery showed a significant improvement in seed germination (Table 1), 79% in seed-cum-fertilizer drill and in 88 strip till drill compared with 73% in local seed drill. This was due to placement of seed and fertilizer in the moist zone from where the germinating roots could obtain required amount of moisture and nutrients quite easily and germinate in higher proportions. In strip till drill treatment, since the preparatory tillage and sowing was done in a single operation, there was negligible loss of soil moisture and thus most of the seeds placed in the soil (88%) could germinate. The seed requirement under this treatment was also reduced from 125 to 75 kg, a saving of 50 kg seed. Due to proper adjustment mechanism available in the machine this was possible. It also reduced plants/m² (60/m²). Similar results were also reported by Shukla *et al* (1996). The re-

Table 1. Effect of seeding machine and planting density on growth and yield attributes of soybean

Treatment	Germination (%)	Plant population/ m²	Plant height (cm)	Branches/ plant	Dry matter (g/plant)	Filled pods/ plant	Unfilled pods/ plant	Seeds/ pod	Seed yield/ plant (g)	1,000-seed weight (g)	Damage due to pest (%)
Seeding machinery											
Local seed drill	73.5	67.1	92.86	8.5	54.2	27.0	4.4	2.15	5.54	115.9	18.0
Improved seed-cum fertilizer drill	79.0	64.6	85.76	10.5	56.0	30.0	3.6	2.19	6.50	118.1	15.5
Strip till drill	88.5	60.1	83.66	11.0	58.9	35.5	2.8	2.20	7.94	118.8	15.0
CD (P=0.05)	0.66	0.96	0.49	0.60	0.69	1.57	1.50	NS	0.70	0.96	1.3
Planting density ('000/ha)											
888	79.5	86.3	96.46	5.5	50.8	20.3	6.0	2.12	4.26	110.4	32.0
666	80.0	65.3	88.01	9.0	55.1	28.3	3.6	2.13	5.32	116.2	15.0
533	80.0	59.3	84.41	11.5	58.2	34.8	3.0	2.22	6.58	119.3	11.4
444	80.5	45.8	80.81	14.0	61.4	39.3	1.8	2.25	8.54	124.5	7.0
CD (P=0.05)	NS	1.22	0.67	0.89	1.06	1.20	1.30	NS	0.40	1.70	1.0

Table 2. Effect of seeding machine and planting density on seed yield of soybean

Treatment	1997–98	1998–99	1999–2000	2000–01	Pooled mean
Seeding machinery					
Local seed drill	11.12	12.89	9.13	10.06	11.80
Improved seed-cum-fertilizer drill	12.67	14.19	10.08	10.51	13.86
Strip till drill	13.72	15.34	11.50	11.21	14.46
CD (P=0.05)	0.10	0.07	0.13	0.07	1.10
Planting density ('000/ha)					
888	10.98	12.26	8.68	9.18	10.27
666	11.73	13.90	9.63	9.13	12.30
533	13.33	14.65	10.68	10.58	14.30
444	13.98	15.75	12.08	12.68	16.62
CD (P=0.05)	0.13	0.06	0.09	0.09	1.03

duced number of plants/m^2 were further responsible for reduced competition between plants for growth resources such as moisture, nutrients, light and CO_2 which favourably influenced the dry matter and branching and reduced plant height compared with farmers seed drill, confirming the results of Baker (1976). Improved seed-cum-fertilizer drill also produced significantly higher dry matter and branches/plant over farmers' practice (Table 1). Donald (1963) reported that with the reduced plant population there was an improvement in dry matter yield due to increased intensity of light received by the individual plant canopy which was apparently spread over greater leaf area and thus reduced mutual shading effects. Due to this, the incidence in soybean crop was reduced from 18% in local drill to 15% in strip till drill.

The favourable effects of improved seeding machinery on growth attributes also reflected positively on the yield attributes like number of filled pods, seeds/pod, seed yield/plant, 1,000-seed weight (Table 1) and ultimately on the seed yield of soybean (Table 2). The above parameters were significantly improved under strip till drill over improved seed-cum-fertilizer drill and local drill, the later also proved significantly superior to local seed drill. The results confirm those of Shukla *et al.* (1996). The increase in yield under strip till drill was 22.5% and 4.3% over local drill and seed-cum-fertilizer drill respectively. These results further indicated that with optimum seed rate (75 kg/ha) placed at proper depth, the optimum plant population (600,000/ha) could be obtained with the use of improved seeding machinery which helped in better growth and development and yield of soybean.

The time required for land preparation and sowing was reduced by 40 min. in seed-cum-fertilizer drill and by 3.15 hr/ha in strip till drill, as only 1 harrowing was necessary before the operation of the strip till drill (Table 3). The cost of operation was also reduced by Rs.578/ha over the local drill. However, the major cost saving was achieved through the reduced quantity of seed requirement for sowing under strip till drill (reduced from 125 kg to 75 kg with a saving of Rs 1,000/ha). This considerably economized the use of strip till drill (Rs 1,578/ha) and improved the net returns by Rs 3,703/ha over local drill. This was followed by ferti-seed drill with net inrome of Rs 2,583/ha over local drill. The benefit : cost ratio was also increased from 1.34 to 2.58 (ferti-seed drill) and 3.71 (strip till drill).

Effect of planting density

Planting density significantly influenced the growth of soybean over the years. It was revealed (Table 1) that a high planting density of 888,000/ha (22.5 cm× 5 cm) in farmer's practice significantly increased the plant height to 96.46 cm compared with 80.81 cm under low planting density of 444,000/ha (45 cm × 5 cm). Although the dry matter produced/plant was lowest (50.8 g/plant) under the high plant density, the total dry matter produced was highest (4,511 kg/ha) compared with low plant density (2,720 kg/ha). The seed requirement (Table 3) for sowing was the highest (135 kg/ha) under high plant density, as the seed germination under different plant densities remained unaffected. The branches and dry matter produced/plant were also increased significantly as the planting density decreased from 888,000 to 444,000 (Table 1). Maximum dry biomass production of 61.4 g/plant and 14 branches/plant were recorded under the planting density of 444,000/plant, followed by 58.2 g/plant biomass and 11.5 branches/plant under 533,000/ha density. This may be ascribed to reduced competition between plants for moisture, soil nutrients and light interception (Rao *et al.* 2003). The effects also indicate that at low plant density, the assimilates supplies to an individual plant was sufficiently high to sustain numerous vegetative sink (Arnon, 1992).

The higher amount of biomass produced under farmer's practice increased the problems of insect incidence of

Table 3. Effect of seeding machinery and planting density on seed yield and economics of soybean

Treatment	Time required (hr) Land preparation	Time required (hr) Sowing of seed	Cost of operation (Rs/ha)	Quantity of seed required	Cost of seed (Rs/ha)	Total cost (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha)	Income over control	benefit : ratio (Rs/ha)
Seeding machinery										
Local seed drill	5.00	2.40	1,530	125	2,500	4,030	9,440	5,410		1.43
Improved seed-cum-fertilizer drill	5.00	2.00	1,295	90	1,800	3,095	11,088	7,993	2,583	2.58
Strip till drill	1.40	2.45	952	75	1,500	2,452	11,568	9,113	3,703	3.71
Planting density ('000/ha)										
888		3.03	1,394	135	2,700	4,094	8,216	4,122		1.00
666		2.40	1,336	100	2,000	3,336	9,840	6,504	2,382	1.95
533		2.20	1,200	82	1,640	2,840	11,444	8,600	4,478	3.03
444		1.53	1,105	70	1,400	2,505	13,296	10,791	6,669	4.31

semilooper and pod borers (Table 1). The damage caused was as high as 32% compared with only 7% under low density. This indicated that high biomass and height provided more space for the hide-out of the insect pests which caused depressing effects on growth parameters and yield. Balyan and Mohta (1985) also observed similar results.

The plant performance in terms of yield-attributing characters such as filled and unfilled seeds/plant, seeds/pod, seed yield/plant and 1,000-seed weight were also significantly improved with the decrease in planting density from 888,000 to 444,000/ha. The maximum values were recorded at the lowest planting density of 444,000/ha. This was ascribed mainly to the increase in assimilate supply to the individual plants due to reduced competition and higher dry matter accumulation at low planting density. Similar results were also reported by Yadav *et al.* (1999).

The positive effects of low density cropping of 444,000/ha on growth and yield attributes of the individual plants ultimately reflected in the significant improvement in seed yield of soybean (Table 2). The pooled seed yield increased from 10.27 q/ha in farmers' practice to 16.62 q/ha in low density cropping (61.8%). The results are in accordance with Veeramani *et al.* (2000). The seed yield at 666,000 and 533,000/ha planting densities were also significantly superior to farmers practice of 888,000/ha and also among themselves, thereby indicating that the reducing planting densities at all levels left their positive influence on seed yield (Yadav *et al.* 1999).

Economic evaluation of the planting densities (Table 3) revealed that lowest density of 444,000/ha was found most remunerative with regard to reduction in time required for sowing (1.50 hr/ha) seed requirement (65 kg/ha) and total cost of treatment (Rs 1,589/ha). Besides, it increased net returns by Rs 6,669/ha (161.8% higher) and benefit : cost ratio 4.31 compared with the control (1.00). Benefit : cost ratio of 1.95 and 3.03 was recorded at plant densities of 666,000 and 533,000/ha respectively.

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