

Effect of methods of crop establishment on productivity and economics of Bt-cotton (*Gossypium hirsutum*)–based intercropping systems

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ABSTRACT

A field experiment was conducted at New Delhi during the rainy (*khari*) season of 2012, to study the effect of methods of crop establishment, planting geometry and intercrops on yield attributes, productivity and economics of Bt-cotton (*Gossypium hirsutum* L.)–based intercropping systems. Seed-cotton yield (3.22 tonnes/ha) was 5.23% higher under transplanting than direct sowing, while seed-cotton equivalent yield of intercrop (0.52 t/ha) was 52% higher under direct sowing. Production efficiency (17.7 kg/ha/day) and net benefit: cost ratio (1.92) were also recorded higher under transplanting. Cotton planted at 90 cm × 60 cm spacing recorded significantly higher yield attributes, seed-cotton yield (3.27/3.01 tonnes/ha), system productivity (3.69/3.45 tonnes/ha), production efficiency (18.6/16.6 kg/ha/day), net returns (₹92.2/80.2 × 10³/ha) and benefit: cost ratio (1.99/1.82) than 120 cm × 45 cm planting. Sole cotton recorded 3.25 tonnes seed-cotton yield/ha, which was 6.2% and 4.2%, higher than the seed-cotton yield recorded in association with okra [*Abelmoschus esculentus* (L.) Moench] and cowpea [*Vigna unguiculata* (L.) Walp.] respectively. Seed-cotton equivalent of cowpea as an intercrop was 10% higher than okra. Cotton + cowpea intercropping system recorded significantly highest system productivity (3.56 tonnes/ha), production efficiency (18.3 kg/ha/day) and net returns (₹86.2 × 10³/ha), while the benefit: cost ratio (2.18) was the highest in sole cotton.

Key words: Cotton, Cowpea, Direct sowing, Intercropping, Okra, Planting geometry, Seed-cotton yield, Transplanting

Cotton popularly known as ‘white gold’, is one of the most important commercial crops in the world. Cultivation of Bt cotton hybrids has resulted in higher productivity at reduced cost of production and environmental pollution. The actual yield level of May–June sown Bt. cotton in north-west part of India is low compared to the potential productivity due to poor germination and high rate of seedlings mortality after germination due to abnormally high soil temperature (ranging from 48 to 52 °C), resulting in poor plant stand. May–summer sown crop also requires frequent irrigation and repeated gap filling to ensure optimum plant stand. Raising seedlings of cotton in May–June under controlled conditions and their transplanting on the onset of monsoon, may be a way out to ensure optimum plant stand and reduce cost of cultivation through saving

in irrigation, seed and weed management (Sarkar and Malik, 2004). Optimum planting geometry is a very important non-monetary input to ensure efficient use of natural resources and other inputs and thus to get higher productivity. Information on this aspect is still limited with respect to Bt. cotton. With decrease in land per capita and no scope for horizontal expansion of area, there is a need for intensification to increase productivity in a sustainable manner (Caballero *et al.*, 1995). In cotton, there is ample scope for intercropping of vegetable crops owing to wider spacing and slow initial growth. An information on intercropping of vegetable crops with Bt. cotton is meagre. There is much scope to increase the Bt. cotton production by agronomic manipulations such as method of crop establishment, planting geometry and intercropping, therefore present study was conducted to standardise these agro-techniques to enhance the productivity and resource use efficiency in Bt. cotton.

The field experiment was conducted at Indian Agricultural Research Institute, New Delhi, during the rainy season (*khari*) of 2012 on sandy-loam soil, having pH 7.8, electrical conductivity (EC), 0.31 dS/m, and available N,

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P and K in soil 160, 14 and 268 kg/ha respectively. Twelve combinations of 2 methods of planting, viz. Direct sowing and transplanting of cotton, and 2 planting geometry, viz. 90 cm × 60 cm spacing and 120 cm × 45 cm spacing, in the main plots and 3 cropping systems, viz. S₁, Sole Bt. cotton, S₂, Bt. cotton + okra 1:2 row ratio; S₃, Bt. cotton + cowpea (green pods) 1:2 row ratio in the subplots were laid out in a split-plot design and replicated 3 times. As per row-to-row spacing of 2 planting geometry, broad bed and furrow land configuration of 120 cm and 90 cm width having bed of 90 cm and 60 cm respectively, and furrow of 30 cm in each case were made before sowing/transplanting. In direct sowing, 2 seeds of Bt. cotton variety 'Bioseed 6588' were dibbled per hill on 5 June, 2012 in the centre of broad bed at 45 and 60 cm intra-row spacing as per treatment. In intercrop also, 2 seeds were dibbled at the margin of broad bed on both side at intra-row spacing of 15 and 25 cm for cowpea variety 'Pusa Komal' and okra variety 'Hybrid Ganga' respectively. Gap filling and thinning was done to ensure optimum plant stand. For nursery raising, poly glass of 15 cm height were filled with soil and farmyard manure in ratio of 3:1. One seed of Bt. cotton variety 'Bioseed 6588' was sown in each glass on 5 June, 2012 and they were watered alternate day till their transplanting in the field. Transplanting of about 1-month-old seedlings was done on 7 July, 2012 in the centre of the bed at 45 cm and 60 cm intra-row spacing as per treatment by making pit of desired dimension. Intercrops as per treatment were also sown at the time of transplanting on both side of cotton row on the margin of broad bed. Recommended dose of nitrogen (180 kg N/ha) as urea was applied in 2 equal splits—first at sowing/transplanting and remaining half at the appearance of the first flower. The recommended dose of phosphorus (60 kg P₂O₅/ha) as single superphosphate and potassium (50 kg K₂O/ha) as muriate of potash was applied at sowing in case of direct seeding method and at transplanting in transplanted cotton. Direct-sown cotton besides pre-sowing irrigation received 5 irrigations before the onset of monsoon rainfall. Cotton transplanting was done on the onset of monsoon without irrigation. Irrigation to cotton was provided to supplement the rainfall, so both the crop received 1 irrigation in post-rain period. As a prophylactic measures, 1 spray of insecticide was done at the time of flowering of cotton. Picking of green pods of cowpea and fruit of okra was done at appropriate stage till they continued the fruiting. In cotton, picking was done thrice at full boll burst stage manually. Observations on growth and yield attributes were made on 3 tagged plants at harvest stage. Seed-cotton was cleaned and weighed from each net plot for expressing seed-cotton yield in tonne/ha and production efficiency (kg/ha/day) was worked out based on yield

and duration for which field was occupied by the crop. System productivity was worked by converting the economic produce of intercrop to seed-cotton equivalent yield and which was added to the actual seed-cotton yield. Net returns and net benefit: cost ratio was worked out based on system cost of cultivation and gross returns.

In the transplanted cotton, mortality percentage after transplanting was low, resulting in higher plant stand as compared to direct-sown cotton. In the direct-sown cotton, the soil surface temperature was very high (sometimes >50°C) as compared to ambient atmosphere temperature, which attributed to poor germination of direct-seeded cotton and mortality of germinated seed. Due to more mortality of the germinated seeds even after 20 to 30 days after sowing, it was not feasible to maintain optimum plant stand under direct sown cotton (even after repeated gap filling). Similar results were also reported by Kamel *et al.* (2003). Monopodia/plant, bolls/plant and seed-cotton yield/plant were significantly higher under direct sown than transplanted cotton (Table 1). Sympodia per plant and weight per boll were statistically similar in direct sown and transplanted cotton. This decrease in other growth attributes under transplanting may be ascribed to transplanting shock to the crop, resulting in less root development and plant growth compared to direct-sown cotton. Moreover, due to less plant stand under direct sowing as compared to transplanting, crop got more space below and above the ground for its growth and development, which contributed towards higher values of growth and yield attributes. Our findings confirm results of Dong *et al.* (2005).

Despite higher values of yield attributes in direct-sown cotton, seed-cotton yield/ha was 5.23% higher under transplanted cotton, which may be attributed to 14–15% higher plant stand under transplanting than direct-sown cotton (Table 1). However, direct and transplanted cotton recorded statistically similar system productivity, owing to higher yield of intercrop under direct sowing. Production efficiency and benefit: cost ratio were higher in transplanted cotton than direct-sown cotton. Higher production efficiency in transplanted cotton is ascribed to reduction in period the crop occupied the field, while higher profitability ascribed to reduction in cost of cultivation. Pundarikakshudu *et al.* (1992) at Nagpur also reported higher seed cotton yield in transplanting method.

Effect of planting geometry was found significant on sympodia/plant, bolls/plant, seed-cotton yield/plant, seed-cotton yield, system productivity, production efficiency, net returns and benefit: cost ratio, where planting geometry of 90 cm × 60 cm recorded marked improvement in these parameters over 120 cm × 45 cm planting geometry, which may be ascribed to optimization of competition

Table 1. Effect of methods of crop establishment, planting geometry and intercrops on yield attributes, productivity and economics of Bt. cotton based intercropping systems

Treatment	Final plant stand	Monopodia/ plant	Sympodia/ plant	Bolls/ plant	Weight/ boll (g)	Seed-cotton yield/plant (g)	Seed-cotton yield (t/ha)	Seed-cotton equivalent yield of intercrop (t/ha)	System productivity in term of seed cotton yield (t/ha)	Production efficiency (kg/ha/day)	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio
<i>Planting methods</i>												
Transplanted	18,420	2.24	18.07	42.3	5.45	174.97	3.22	0.34	3.56	23.3	86.2	1.92
Direct seeded	15,802	2.44	19.14	45.2	5.49	193.53	3.06	0.52	3.58	19.6	86.3	1.89
SEM \pm	36	0.045	0.363	0.47	0.15	1.420	0.028	0.01	0.025			
CD (P=0.05)	126	0.16	NS	1.65	NS	4.91	0.10	0.05	0.09			
<i>Planting geometry (cm \times cm)</i>												
90 \times 60	17,144	2.33	19.61	45.8	5.52	195.55	3.27	0.42	3.69	21.9	92.2	1.99
120 \times 45	17,077	2.35	17.60	42.1	5.42	172.94	3.01	0.44	3.45	20.5	80.2	1.82
SEM \pm	36	0.045	0.363	0.47	0.15	1.420	0.028	0.01	0.025			
CD (P=0.05)	NS	NS	1.26	1.65	NS	4.91	0.10	0.05	0.09			
<i>Intercropping system</i>												
Sole cotton	17,121	2.40	19.23	45.0	5.65	190.59	3.25		3.25	19.3	82.4	2.18
Cotton + okra	17,190	2.31	18.10	43.1	5.35	178.42	3.06	0.41	3.47	20.6	82.4	1.81
Cotton + cowpea	17,021	2.31	18.49	43.2	5.42	182.73	3.12	0.44	3.56	21.2	86.2	1.91
SEM \pm	129	0.04	0.25	0.26	0.15	2.34	0.03	0.01	0.03			
CD (P=0.05)	NS	NS	0.76	0.79	NS	7.02	0.10	0.03	0.09			

among the plants both under the ground for nutrients and water and above the ground for light, CO₂ and space. Intercrop performed better under wider inter-row spacing of 120 cm, which may be attributed to better ecology available to the crop. Similar results were also reported by Salakinkop (2009) and Bhalerao and Gaikwad Godavari (2010), where planting geometries at the same plant population were found to create differences in growth, yield attributes and final yield.

Sole cotton recorded significantly higher values of sympodia/plant, bolls/plant and seed-cotton yield/plant than intercropped stand. Cotton intercropped with okra and cowpea recorded statistically similar values of yield attributes (Table 1). Between the intercrops, favourable effect of cowpea was observed on the growth, yield attributes and yield of cotton, which may be ascribed to its legume effect on soil health and improving availability of nitrogen to the associated crop. Among cropping systems, sole cotton registered significantly the highest seed-cotton yield (3.25 t/ha.) followed by cotton + cowpea (3.12 t/ha) and cotton + okra cropping system (3.06 t/ha). On the other hands, cotton + cowpea intercropping system registered significantly the highest seed-cotton equivalent yield of intercrops as well as system productivity, production efficiency and net returns followed by cotton + okra system (Table 1). Chellamuthu and Ramaswami (2000) also reported similar results.

From the foregoing discussion, it may be concluded that in the method of crop establishment, raising of nursery and transplanting of seedling at the onset of monsoon is superior to direct sowing of cotton in terms of seed-cotton yield. Planting geometry of 90 cm \times 60 cm optimized natural resource-use efficiency resulted in higher seed-cotton yield. Intercropping of cotton + cowpea was found more productive and economical than sole stand of cotton.

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