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Research Paper

Growth, yield and quality of *Bt* cotton (*Gossypium hirsutum*) as influenced by different intercropping systems and nitrogen levels

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) season of 2010 and 2011 at Ludhiana, Punjab to study the effect of intercrops and different levels of recommended dose of nitrogen (RDN). Applied to intercrops on growth, yield and quality of hybrid *Bt* cotton (*Gossypium hirsutum* L.). The main plot treatments comprised *Bt* cotton intercropped with fodder maize (*Zea mays* L., Saccharata), fodder cowpea [*Vigna unguiculata* (L.) Walp.], summer mungbean [*Vigna radiata* (L.) Wilczek], pearlmillet fodder [*Pennisetum glaucum* (L.) R. Br. emend. Stuntz] and long melon [*Cucumis melo* L. var. *utilissiumus* Duth. & Full.] and subplot treatments consisted of 5 levels (0, 25, 50, 75 and 100%) of recommended dose of nitrogen applied to intercrops on area basis. The maximum seed-cotton equivalent yield recorded under *Bt* cotton + fodder maize intercropping system (2.61 t/ha) was 10.6, 17.6, 27.3 and 39.6% higher than *Bt* cotton + fodder cowpea, *Bt* cotton + summer mungbean, *Bt* cotton + long melon and *Bt* cotton + fodder pearlmillet, respectively. The maximum net returns of ₹49,085 and benefit: cost ratio 2.33 obtained from *Bt* cotton + fodder maize intercropping system were statistically at par that obtained with *Bt* cotton + fodder cowpea (₹41,545 and benefit: cost ratio 2.12) but significantly higher than all the other intercropping systems. The application of 50% recommended dose of nitrogen to intercrops resulted in 7.0 and 12.4% increase in seed-cotton and seed-cotton equivalent yield as compared to no fertilizer application to intercrops. In all the intercropping systems except *Bt* cotton + long melon, application of full dose of nitrogen to *Bt* cotton and 50% of the RDN to intercrops proved beneficial for getting higher seed-cotton equivalent yield and economic returns.

Key words **:** *Bt* cotton, Intercropping, Nitrogen, Seed-cotton equivalent yield, Seed-cotton yield

Cotton is the most important fibre crop in the world and its lint is used to make processed cotton, which is woven into fabrics either alone or combined with other fibres. The seeds contain good percentage of edible oil and residual cake is rich in proteins and used as cattle feed. Intercropping is an important practice to increase total yield per unit area. This system is used in many parts of the world, especially in the regions where small farmers intensively utilize the limited land area (Metwally *et al.,* 2012). In terms of land use, growing crops in mixed stands is regarded as more productive than growing them alone. This may be owing to some of the established and speculated advantages for intercropping systems such as higher total yield, greater land-use efficiency/unit land area and improvement in soil fertility through the addition of nitrogen by fixation and excretion from the component legumes. In intercropping studies, a little emphasis has been made on fertilization issues like (*i*) how to fertilize component species in intercropping system particularly when species respond differently to a particular nutrient, (*ii*) whether legumes modify the nutrient responses of the associated non-legume. Very few studies have actually considered the response of both the components in determining the optimum dose of fertilizer for an intercropping system.

The nutrient requirements of intercropping systems will be different than that that of monocropping. Kote *et al.* (2005) reported that in cotton + blackgram and cotton + soybean intercropping systems, every higher dose of fertilizer application up to 100% of the recommended dose to both the crops resulted in significant increase in seed-cotton yield, intercrop yield, seed-cotton equivalent yield and monetary or economic returns. Meena *et al.* (2006) observed that in maize-based intercropping systems, application of 75% of recommended dose of fertilizer (RDF) to maize (90 kg N/ha) and 50% of RDF to soybean (60 kg N/ha) significantly increased their respective yields, maize-equivalent yield, net returns and benefit: cost ratio over 50% RDF in maize and no fertilizer application to soy-

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bean. Therefore, the present experiment was planned to study growth, yield and quality of hybrid *Bt* cotton when grown in association with tall non-legumes like maize and fodder pearlmillet, short-compact legumes like cowpea fodder and summer mungbean and cucurbits (long melon) with varied levels of nitrogen application (0, 25, 50, 75 and 100% of recommended dose on area basis) to intercrops and recommended dose of nitrogen applied to the hybrid *Bt* cotton. The objective of the study was to find out optimum nitrogen requirement and higher productivity from *Bt* cotton-based intercropping systems.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) season of 2010 and 2011 at the Ludhiana (30°–56' N, 75°–56' E and 247 m above mean sea-level) Punjab. The soil of the experimental site was loamy sand with normal soil *p*H (7.9) and electrical conductivity (0.20 dS/m), low in organic carbon (0.32%), available N (125.4 kg/ha) and K (108.6 kg/ha) but high in available P (20.0 kg/ha). The experiment was laid out in split-plot design with 4 replications. The main plot treatments comprised 5 intercropping systems (*Bt* cotton + fodder maize, *Bt* cotton + fodder pearlmillet, *Bt* cotton + fodder cowpea, *Bt* cotton + summer mungbean and *Bt* cotton + long melon) and sub-plot treatments comprised 5 nitrogen levels to intercrops (0, 25, 50, 75 and 100% of recommended dose of nitrogen to intercrops on area basis). In this experiment, the *Bt* cotton was applied 100% of the recommended dose of fertilizers (N, P and K). Seven rows of *Bt* cotton were accommodated in 4.75 m × 5.00 m plot. *Bt* cotton was planted at row-to-row spacing of 67.5 cm and plant-to-plant spacing of 75 cm. One row of intercrop was sown between 2 rows of the *Bt* cotton. *Bt* cotton hybrid 'RCH 314' was sown by dibbling on a well-prepared seedbed after heavy pre-sowing irrigation on 29 April and 5 May during 2010 and 2011 respectively. The different intercrops viz. fodder maize, fodder pearlmillet, fodder cowpea, summer mungbean and long melon were also sown on the same day. The recommended dose of fertilizer to *Bt* cotton (150 kg N and 30 kg P_2O_5/ha) was applied with half nitrogen at thinning and remaining at the flower initiation. All the phosphorus was applied at the time of sowing. The recommended dose of fertilizer to intercrops was applied on area basis. The recommended dose (100%) of fertilizer applied for fodder maize was 87.5 kg N, 30 kg P_2O_5 and 20 kg K_2O/ha, fodder pearlmillet 50 kg N/ha, fodder cowpea 18.75 kg N and 55 kg P_2O_5/ha, summer mungbean 12.5 kg N and 40 kg P_2O_5/ha and for long melon 100 kg N, 75 kg P_2O_5 and 50 kg K_2O/ha. In fodder maize and pearlmillet, half nitrogen and full dose of phosphorus and potassium were applied at the time of sowing and remaining half nitrogen was applied 4 weeks after sowing. The whole recommended dose of fertilizer for fodder cowpea and summer mungbean was applied at the time of sowing. However, in long melon one-third N, whole P and K were applied at sowing, remaining two-third N was applied in 2 equal splits, one-third 2 weeks after sowing and one-third 4 weeks after sowing. Three foliar sprays of potassium nitrate (N: P: K, 13:0:45) were given at weekly intervals, starting from flower initiation of *Bt* cotton during both the crop seasons. Crop was irrigated as and when required depending on the rainfall and evaporative demand of the atmosphere. The fodder cowpea was harvested 50 days after sowing (DAS) but fodder maize and pearlmillet were harvested at 60 days. The summer mungbean was harvested at physiological maturity (65 DAS) and long melon fruits were picked from 50 to 75 days after sowing. The *Bt* cotton was picked in 3 pickings from the second fortnight of September to the first fortnight of November during both the years.

The meteorological data for both the crop seasons (May to November) have been depicted in Figs. 1 and 2. Total rainfall received during the crop-growing seasons of 2010 and 2011 was 661.2 mm and 1257 mm, respectively, which were above the normal (617 mm) during both the years. The total evaporation during the crop-growing seasons for 2010 and 2011 was 1,103 mm and 984 mm respectively. In general, weather was more favourable for crop growth during 2011 crop season. The cotton seeds were delinted with sulphuric acid and dried first in the shade and then in the oven and oil content was determined using nuclear magnetic resonance spectroscope. Seed-cotton equivalent yield was calculated (t/ha) as:

$$\text{Seed-cotton yield} + \frac{\text{Intercrop yield (t/ha)} \times \text{Price of intercrop (₹/t)}}{\text{Sale price of } Bt \text{ cotton (₹/t)}}$$

The soil sample from 0–15 cm depth were taken from the experimental field before sowing of the experiment

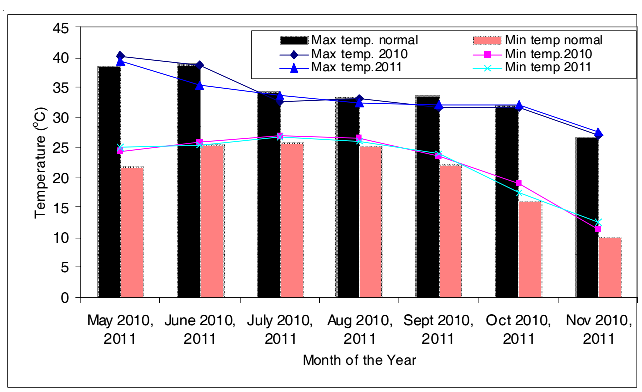

Fig. 1. Temporal changes in temperature during the crop-growing seasons.

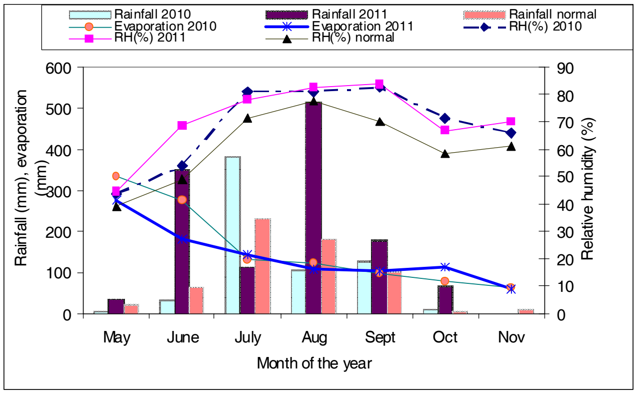

Fig. 2. Temporal changes in rainfall, evaporation and relative humidity during crop-growing seasons.

and after removal of cotton sticks of *Bt* cotton during both the years. The soil samples were dried in the shade, sieved and analysed for available NPK. The plant samples after recording observations were dried in oven at 65ºC. The samples were made composite and after grinding into fine powder used for analysis of nitrogen. The nitrogen content (%) of plant material was determined by Kjeldahl's method. The collected data was analysed using analysis of variance technique.

RESULTS AND DISCUSSION

Growth of Bt cotton

The data on pooled basis revealed that *Bt* cotton intercropped with fodder pearlmillet recorded significantly lower plant height than all the intercropping systems from 60 days after sowing till maturity (Fig. 3). The dry-matter accumulation recorded by *Bt* cotton intercropped with fodder pearlmillet intercropping system was significantly lower than all other intercropping systems throughout the growing period. This was because of tillering nature and more profuse growth of fodder pearlmillet planted at 67.5 cm apart rows. At 60 days, maximum and significantly higher dry matter was accumulated in *Bt* cotton + long melon, which was statistically at par with *Bt* cotton + summer mungbean and *Bt* cotton + maize but significantly better than *Bt* cotton + fodder cowpea. This may be because of the reason that *Bt* cotton when intercropped with long melon got ample sunlight during early stages of crop growth, while in the other intercropping systems plants remained under shade of intercrop to varying degree. From 90 days till maturity cotton plants in *Bt* cotton + summer mungbean system recorded maximum dry-matter, may be because that nitrogen fixed in the nodules of summer mungbean was utilized by the *Bt* cotton plants (Fig 4). The maximum leaf-area index (LAI) of *Bt* cotton recorded at 120 days, in all the intercropping systems except *Bt* cotton intercropped with fodder pearlmillet was statistically at par with each other (Fig. 5). This may be attributed to higher light interception by pearlmillet in intercropping system than sole cropping, which resulted in shading and lower photosynthetically active radiation (PAR) interception by cotton in lower layers of the canopy.

With different doses of nitrogen applied to intercrops the plant height of *Bt* cotton was significantly influenced up to 90 days. At later stages, the plant height of *Bt* cotton was statistically at par with application of different doses of nitrogen to intercrops. From 60 days after sowing, at all the growth stages, the application of 50% recommended dose of nitrogen to intercrops significantly increased dry-matter accumulation by *Bt* cotton over the control.

Further increased dose of nitrogen applied to intercrops failed to significantly increase the dry matter accumulation of *Bt* cotton. The application of 75% RDN to intercrops significantly increased the LAI of *Bt* cotton, as compared to all other nitrogen levels at 90 and 120 DAS. At all the growth stages, lowest LAI was recorded in control treatment (no nitrogen application to intercrops).

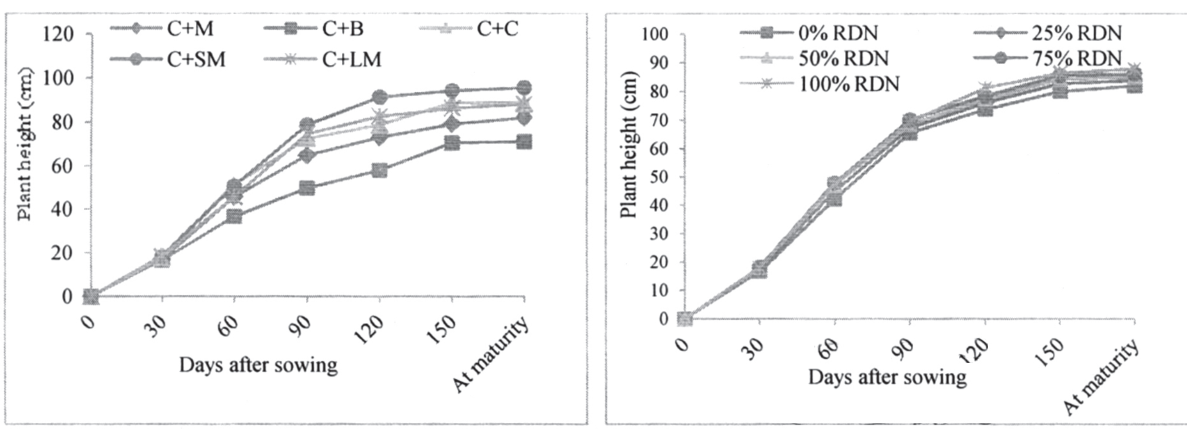

Fig. 3. Plant height of *Bt* cotton as influenced by intercropping systems and RDN to intercrops (pooled data).

Yield of intercrops

Application of 75% RDN to intercrops like fodder maize and pearlmillet resulted in yield increase of 44.2 and 36.2% compared to control plot (Table 1). The application of 50% of the RDN to fodder cowpea increased the green fodder yield by 16.0% over the control. The magnitude of yield increase with further higher dose of applied fertilizer was very low in this crop. The application of 75% of the RDN increased grain yield of summer mungbean by 33.9% compared to the control. The lower grain yield of summer mungbean was due to the occurrence of more rainfall in May and June during the second year (Fig. 2) which resulted in increased vegetative growth and poor pod development. The fruit yield of long melon was increased to the tune of 47.2% with the application of 75% of the RDN over the control. Further increase in fertilizer dose beyond 75% of the RDN failed to increase the yield of intercrops. Similarly, Rekha and Dhuria (2010) reported that in cotton + soybean intercropping system maximum seed-cotton equivalent yield was obtained with RDF to cotton + RDF to soybean on row proportionate basis.

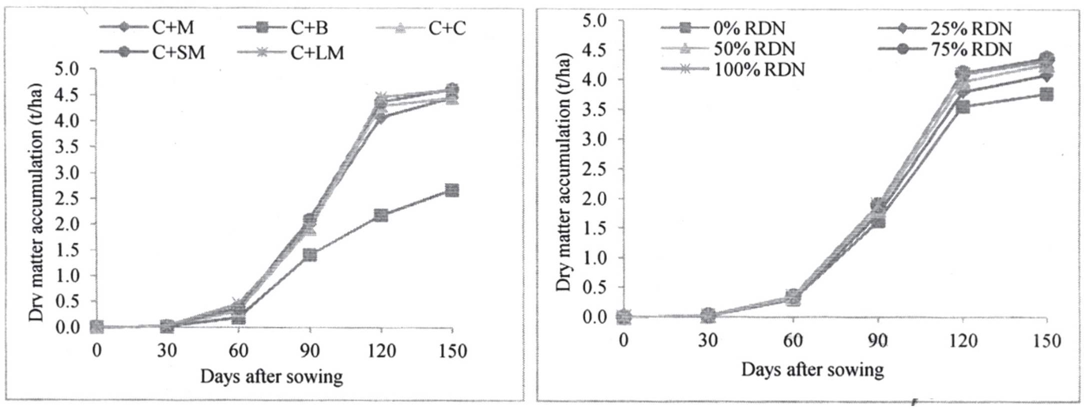

Fig. 4. Dry matter accumulation of *Bt* cotton as influenced by intercropping systems and recommended dose of nitrogen (RDN) to intercrops (pooled data).

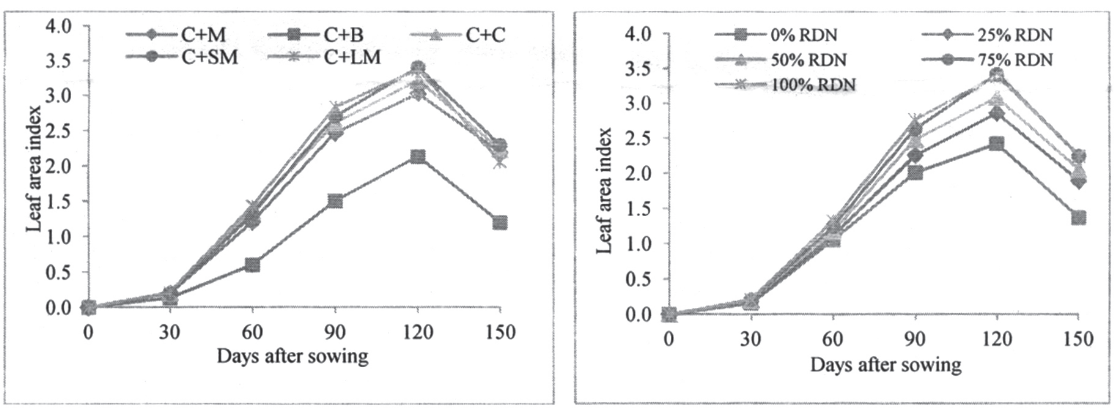

Fig. 5. Leaf-area index of *Bt* cotton as influenced by intercropping systems and recommended dose of nitrogen (RDN) to intercrops (pooled data).

Table 1. Effect of different levels of recommended dose of nitrogen to intercrops on the yield of intercrops (pooled data of 2 years)

% RDN to intercrops	Intercrops yield (t/ha)					
	Maize (fodder)	Pearlmillet (fodder)	Cowpea (fodder)	Summer mungbean	Long melon	Mean
0	16.5	22.1	14.4	0.59	0.72	10.9
25	20.8	26.0	15.9	0.72	0.89	12.9
50	22.8	29.1	16.7	0.76	1.02	14.1
75	23.8	30.1	16.9	0.79	1.06	14.5
100	24.1	30.7	17.0	0.80	1.07	14.7
Mean	21.6	27.6	16.2	0.73	0.95	

Effect of intercropping systems and N levels applied to intercrops on yield and yield attributes of Bt cotton

Among the different intercropping systems, maximum number of opened bolls/plant were recorded in *Bt* cotton intercropped with long melon, which were statistically at par with all the other *Bt* cotton-based intercropping systems except *Bt* cotton intercropped with fodder pearlmillet, which recorded significantly lower number of opened bolls/plant (Table 2). Similar trend was observed for total number of bolls/plant. The boll opening percentage was not significantly influenced by different intercropping systems. The boll weight in *Bt* cotton intercropped with fodder pearlmillet was statistically at par with *Bt* cotton + fodder maize, but significantly lower than all the other intercropping systems. Maximum seed-cotton yield was recorded in *Bt* cotton + long melon intercropping system and it was statistically at par with *Bt* cotton + fodder maize and *Bt* cotton + summer mungbean. The significant reduction in seed-cotton yield was recorded with *Bt* cotton + fodder pearlmillet intercropping system as compared to all the other intercropping systems. *Bt* cotton + fodder cowpea intercropping system also recorded significant yield reduction compared to *Bt* cotton + long melon. It may be due to adverse effect of fodder pearlmillet on *Bt* cotton with the production of tillers more profusely causing shading of cotton plants resulting in reduced photosynthesis besides competition for nutrients and moisture. Cowpea fodder also caused shading on *Bt* cotton plants due to its quick growth habit.

Different levels of RDN applied to intercrops resulted in significant increase in number of opened and total bolls/plant in *Bt* cotton up to 50% RDN applied to intercrops. The number of unopened bolls/plant and boll opening percentage were not significantly affected by different levels of RDN applied to intercrops. The boll weight was significantly increased up to 25% of RDN applied to intercrops. Seed-cotton yield was significantly increased up to 50% of RDN applied to intercrops and further increased dose did not significantly increase the seed cotton yield.

Seed-cotton equivalent yield

Among the different intercropping systems, the maximum seed-cotton equivalent yield was recorded in *Bt* cotton + fodder maize, which was statistically at par with *Bt* cotton + fodder cowpea, but was significantly superior to all the other intercropping systems (Table 3). The lowest seed-cotton equivalent yield was obtained from *Bt* cotton + fodder pearlmillet intercropping system. This was because of severe reduction in seed-cotton-yield, when *Bt* cotton was intercropped with fodder pearlmillet. However, *Bt* cotton + fodder pearlmillet intercropping system recorded seed-cotton equivalent yield statistically at par with *Bt* cotton + long melon. Similar findings were also reported by Rajpoot *et al.* (2014).

The different levels of RDN applied to intercrops resulted in significant increase in the seed-cotton equivalent yield, with the application of 75% RDN to intercrops resulted in significantly higher seed-cotton equivalent yield than 50% RDN, 25% RDN and control plots. The further increase in nitrogen dose up to 100% of RDN did not significantly influence the seed-cotton equivalent yield. The interaction between intercropping systems and RDN to

Table 2. Effect of different intercropping systems and recommended dose of nitrogen (RDN) to intercrops on opened bolls, un-opened bolls, total bolls, boll opening percentage and boll weight of *Bt* cotton (pooled data of 2 years)

Treatment	Opened bolls/plant	Un-opened bolls/plant	Total bolls/plant	Boll opening percentage	Boll weight (g)
Intercropping systems (1 + 1)					
Bt cotton + fodder maize	28.9	3.81	32.7	88.3	3.60
Bt cotton + fodder pearlmillet	20.6	3.68	24.3	85.0	3.47
Bt cotton + fodder cowpea	29.5	4.04	33.6	87.9	3.66
Bt cotton + summer mungbean	30.3	4.82	35.1	86.5	3.68
Bt cotton + long melon	31.5	4.24	35.7	88.3	3.68
SEm±	1.73	0.25	1.47	3.3	0.06
CD (P=0.05)	3.45	NS	3.94	NS	0.15
RDN to intercrops (%)					
0	25.1	3.71	28.8	87.1	3.53
25	27.9	4.07	32.0	87.5	3.61
50	29.1	4.25	33.4	87.2	3.66
75	29.4	4.18	33.6	87.3	3.67
100	29.3	4.38	33.7	87.0	3.61
SEm±	0.34	0.14	0.52	2.09	0.03
CD (P=0.05)	1.10	NS	1.33	NS	0.07

intercrops was significant for seed-cotton equivalent yield. *Bt* cotton + maize fodder, *Bt* cotton + fodder pearlmillet with the application of 50% RDN recorded seed-cotton equivalent yield which was statistically at par with that obtained from 75% of the RDN, but significantly higher than 25% RDN. *Bt* cotton + cowpea fodder and *Bt* cotton + summer mungbean application of 50% RDN recorded seed-cotton equivalent yield, which was statistically at par with that obtained from both 25 and 75% of the RDN, while in *Bt* cotton + long melon intercropping system 25% of the RDN recorded seed-cotton equivalent yield, which was statistically at par with all the higher levels of RDN. The interaction effects (Table 4) further indicated that in all the Bt cotton based intercropping systems except *Bt* cotton + long melon seed-cotton equivalent yield obtained with 50% of RDN was statistically at par with 75 and 100% of the RDN. While, Bt cotton+ long melon responded only up to 25% of the RDN. This may be because of the fact that in this intercropping system, when plant starts fruiting, after a few days the rainy season starts, which reduces the yield of long melon because of severe attack of insect-pests and rotten fruit. Contrary to this, Ramanjaneyulu and Reddy (2002) reported that in cotton + groundnut and cotton + soybean intercropping system, application of 100% recommended dose of fertilizer (RDF) N and P to both the crops resulted in higher seed-cotton-equivalent yield than 100% RDF to cotton and no fertilizer application to intercrop or 75% of RDF to cotton + 100% RDF to intercrops. Krishnasamy *et al.* (1995), Kote *et al.* (2005) and Giri *et al.* (2006) reported that in cotton + blackgram or cotton + soybean intercropping system, every higher level of nitrogen application to both the crops resulted in significantly higher seed-cotton equivalent yield than to 50 or 75% of the recommended dose.

Quality of Bt cotton as influenced by intercropping systems and nitrogen application to intercrops

Quality parameters, viz. ginning outturn, 100-seed weight/seed index and lint index were not significantly influenced by different intercropping systems (Table 5). Different levels of nitrogen application to intercrops also failed to significantly influence these parameters. However, oil content in *Bt* cotton was significantly influenced by different intercropping systems. *Bt* cotton + fodder maize and Bt cotton + fodder cowpea recorded significantly higher oil content than *Bt* cotton + fodder pearlmillet and *Bt* cotton + summer mungbean but were statistically at par with *Bt* cotton + long melon.

Available nutrients (NPK) after harvest of Bt cotton

Different intercropping systems significantly affected available nitrogen content in the soil (Table 6). The available nitrogen content in the soil after harvesting of *Bt* cotton remained statistically similar among all the intercropping systems except when *Bt* cotton intercropped with

Table 3. Effect of different intercropping systems and recommended dose of nitrogen (RDN) to intercrops on intercrop yield, seed-cotton yield, seed-cotton equivalent yield, net returns and benefit: cost ratio of *Bt* cotton (pooled data of 2 years)

Treatment	Intercrop yield (t/ha)	Seed cotton yield (t/ha)	Seed cotton equivalent yield (t/ha)	Net returns (×10³ ₹/ha)	Benefit: cost ratio
Intercropping systems (1 + 1)					
Bt cotton + fodder maize	21.6	1.73	2.61	49.1	2.33
Bt cotton + fodder pearlmillet	27.6	0.99	1.87	25.9	1.73
Bt cotton + fodder cowpea	16.2	1.71	2.36	41.6	2.12
Bt cotton + summer mungbean	0.36	1.84	2.22	36.7	1.98
Bt cotton + long melon	0.95	1.90	2.05	31.6	1.85
SEm ±	–	0.08	0.12	3.5	0.09
CD (P=0.05)	–	0.19	0.30	9.7	0.26
RDN to intercrops (%)					
0	10.8	1.55	2.02	30.8	1.85
25	12.8	1.63	2.19	36.2	1.99
50	14.0	1.66	2.27	38.7	2.04
75	14.4	1.67	2.30	39.5	2.07
100	14.7	1.66	2.31	39.5	2.06
SEm±	–	0.01	0.01	0.39	0.01
CD (P=0.05)	–	0.03	0.03	1.13	0.03

Selling price (pooled) *Bt* cotton ₹31,500/t; fodder maize ₹1,275/t; fodder pearlmillet ₹1,000/t; fodder cowpea ₹1,275/t; summer mungbean ₹33,375/t; long melon ₹5,000/t; cotton sticks ₹950/t fodder pearlmillet, which recorded significantly low available nitrogen content in the soil. The nitrogen content in the soil varied significantly with the different levels of nitrogen applied to intercrops. The application of 50, 75 and 100% RDN showed statistically similar but significantly higher nitrogen content in soil than control. The available phosphorus and potassium status of the soil was not significantly influenced by different intercropping systems and RDN applied to the intercrops.

N content in plants and uptake

The N content in *Bt* cotton plants was significantly different among the different intercropping systems, being lowest in *Bt* cotton plants intercropped with fodder pearlmillet. Various levels of RDN applied to the intercrops did not significantly influence N content of cotton plants. In different levels of RDN applied to intercrops, *Bt* cotton plants recorded the lowest nitrogen content where no nitrogen was applied to intercrops (Table 7). Among the intercrops, nitrogen content was significantly lower in fodder pearlmillet and fodder maize than in summer mungbean, cowpea or long melon. The application of 50% recommended dose of fertilizer to intercrops recorded significantly higher nitrogen content than the control plot; however, it was statistically at par with 75% RDN but significantly lower than 100% RDN.

The nitrogen uptake by *Bt* cotton was significantly different in various intercropping systems. *Bt* cotton intercropped with summer mungbean recorded the maximum N uptake, which was statistically at par with all the other intercropping systems except *Bt* cotton + fodder pearlmillet intercropping system and *Bt* cotton + fodder maize. The application of 50% RDN to intercrops resulted in significantly higher nitrogen uptake by *Bt* cotton plants than those where no nitrogen was applied to the intercrops. However, nitrogen uptake by *Bt* cotton plants with application of 50% RDN to intercrops was statistically at par with application of 100% RDN to intercrops. Differ-

Table 4. Interaction of intercropping systems and recommended dose of nitrogen (RDN) to intercrops on seed-cotton-equivalent yield (t/ha) (pooled data of 2 years)

Intercropping systems (1+1)	*RDN to intercrops (%)*					
	0	25	50	75	100	Mean
Bt cotton + fodder maize	2.29	2.56	2.69	2.74	2.75	2.61
Bt cotton + fodder pearlmillet	1.60	1.82	1.95	1.99	2.00	1.87
Bt cotton + fodder cowpea	2.24	2.34	2.40	2.41	2.42	2.36
Bt cotton + summer mungbean	2.06	2.21	2.26	2.29	2.30	2.22
Bt cotton + long melon	1.92	2.05	2.08	2. 09	2.10	2.05
Mean	2.02	2.20	2.28	2.30	2.31	
	Intercropping systems		RDN to intercrops (RDNI)		IS × RDNI	
SEm±	0.12		0.01			
CD (P=0.05)	0.30		0.03		0.07	

Table 5. Effect of different intercropping systems and recommended dose of nitrogen (RDN) to intercrops on ginning outturn, seed index, lint index and oil content of *Bt* cotton (pooled data of 2 years)

Treatment	Ginning outturn (%)	Seed index (g)	Lint index (%)	Oil content (%)
Intercropping systems (1+1)				
Bt cotton + fodder maize	34.9	8.12	4.45	17.4
Bt cotton + fodder pearlmillet	35.4	7.92	4.55	16.4
Bt cotton + fodder cowpea	34.5	8.37	4.62	17.4
Bt cotton + summer mungbean	35.4	8.00	4.35	16.3
Bt cotton + long melon	35.3	8.06	4.48	16.9
SEm±	0.57	0.22	0.34	0.24
CD (P=0.05)	NS	NS	NS	0.69
RDN to intercrops (%)				
0	35.5	7.97	4.53	16.4
25	35.3	8.09	4.42	17.0
50	35.0	8.16	4.50	17.0
75	34.9	8.15	4.39	17.1
100	34.8	8.10	4.48	16.8
SEm±	0.40	0.21	0.23	0.17
CD (P=0.05)	NS	NS	NS	NS

Table 6. Effect of different intercropping systems and recommended dose of nitrogen (RDN) to intercrops on available N, P and K content (kg/ha) in soil after the harvest of *Bt* cotton (pooled data of 2 years)

Treatment	Available nutrients in soil (Kg/ha)		
	N	P	K
Intercropping systems (1 + 1)			
Bt cotton + fodder maize	127.6	19.4	93.4
Bt cotton + fodder pearlmillet	100.7	18.7	89.8
Bt cotton + fodder cowpea	129.6	20.1	96.2
Bt cotton + summer mungbean	130.8	19.9	96.9
Bt cotton + long melon	121.8	20.6	94.0
SEm±	3.91	1.01	2.86
CD (P=0.05)	9.5	NS	NS
RDN to intercrops (%)			
0	113.7	20.2	95.6
25	117.5	19.3	95.6
50	125.4	20.0	94.5
75	127.8	19.9	93.6
100	126.7	19.3	91.9
SEm±	3.56	0.89	2.16
CD (P=0.05)	8.9	NS	NS

Soil initial status: N, 125.4 kg/ha; P, 20.0 kg/ha; K, 108.6 kg/ha

ent intercrops fodder maize and pearlmillet recorded significantly higher N uptake than summer mungbean, cowpea and long melon during both the years. Different levels of RDN applied to intercrops showed that application of 75% RDN to intercrops resulted in significant increase in N uptake with the control plot, i.e. no-nitrogen application. The nitrogen uptake recorded with 75% RDN was statistically at par with 100% RDN. Raju and Thakare (2013) also reported that *Bt* cotton-based intercropping systems require nitrogen nutrient in proportion to their population of intercrop.

Economics

The maximum net returns obtained from *Bt* cotton + fodder maize intercropping system being statistically at par with *Bt* cotton + fodder cowpea were significantly higher than *Bt* cotton + fodder pearlmillet intercropping system, *Bt* cotton + long melon and *Bt* cotton + summer mungbean intercropping systems. Different levels of RDN applied to intercrops gave significantly higher net returns than the control. However, the application of 50, 75 and 100% of the RDN applied to the intercrops recorded statistically similar net returns, but these levels resulted in significantly higher net returns than those obtained from 25% of the RDN applied to intercrops (Table 3). Benefit: cost ratio differed significantly due to different intercropping systems. The maximum benefit: cost ratio was recorded from *Bt* cotton + maize intercropping system which was statistically at par with *Bt* cotton + fodder cowpea but significantly higher than *Bt* cotton + fodder pearlmillet, *Bt* cotton + long melon and *Bt* cotton + summer mungbean intercropping systems. The application of different levels of RDN to intercrops resulted in significant differences in the benefit: cost ratio. Application of 50, 75 and 100% of RDN to intercrops recorded statistically similar benefit: cost ratio; however, these levels were significantly better than the 25% RDN.

Thus, on the basis of seed-cotton equivalent yield and economic returns, *Bt* cotton-based intercropping systems like *Bt* cotton + fodder maize, *Bt* cotton + fodder cowpea were found to be superior to all the other intercropping

Table 7. Effect of different intercropping systems and recommended dose of nitrogen (RDN) to intercrops on nitrogen content and N uptake in *Bt* cotton and intercrops (pooled data of 2 years)

Treatment	N content in *Bt* cotton (%)	N uptake by *Bt* cotton (kg/ha)	N content in intercrops (%)	N uptake by intercrops (kg/ha)
Intercropping systems (1+1)				
Bt cotton + fodder maize	2.57	114.1	1.63	76.4
Bt cotton + fodder pearlmillet	2.40	64.3	1.61	87.5
Bt cotton + fodder cowpea	2.65	118.4	2.69	57.5
Bt cotton + summer mungbean	2.62	121.3	2.73	38.9
Bt cotton + long melon	2.55	117.9	2.49	9.1
SEm±	0.05	2.57	0.08	5.2
CD (P=0.05)	0.16	6.30	0.22	14.0
RDN to intercrops (%)				
0	2.45	92.8	2.09	42.9
25	2.55	104.5	2.16	50.7
50	2.60	111.6	2.26	56.0
75	2.58	113.6	2.29	59.0
100	2.60	113.2	2.40	61.1
SEm±	0.03	2.75	0.05	1.45
CD (P=0.05)	NS	7.29	0.13	3.99

systems. In *Bt* cotton based-intercropping systems for getting higher seed-cotton equivalent yield and economic returns, full dose of nitrogen to *Bt* cotton and 50% of the RDN to intercrops like fodder maize, fodder pearlmillet, fodder cowpea and summer mungbean may be recommended, while in long melon 25% of the RDN may be applied as indicated by interaction effects.

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