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Performance of intercrops in *Bt* (*Bacillus thuringiensis*) cotton (*Gossypium hirsutum* L.) hybrid and assessment of its refugia system

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ABSTRACT : A intercropping study involving a *Bt* hybrid MECH 162 *Bt* was carried out at CICR, Regional Station, Coimbatore during winter irrigated season (August to February) of 2003-2004 and 2004-2005 to find out the best suitable intercrop in addition to the assessment of the existing refugia system of *Bt* + 20 per cent non *Bt* cotton (4:1). The treatments comprised of intercropping of two rows of redgram, cowpea, onion and *bhendi* planted between a pair of *Bt* cotton at 105 cm row spacing. In *Bt* cotton + 20 per cent non *Bt* treatment, 20 per cent non *Bt* was planted in surrounding of the plot, in addition to that of pure *Bt* cotton and non *Bt* cotton Bunny, were tested in randomized block design with three replications. None of the above treatments influenced crop growth, seed cotton yield and quality parameters of the base crop of cotton. It further revealed that no significant yield differences were seen between sole *Bt* and refugia cropping of *Bt* + non *Bt* (4:1) as recommended for cultivation of *Bt* cotton . Economic analysis indicated that highest benefit cost ratio (1.6) and net returns (Rs. 49,718) were recorded with *Bt* cotton + *bhendi* intercropping system. Highest seed cotton equivalent yield (31.69 q/ha), crop profitability (Rs. 331/ha/day), relative production (53.0) and economic efficiency (84.2) were also evident in the above intercropping system although maximum land (1.88) and income (1.71) equivalent ratios were with *Bt* cotton + cowpea.

Key words : *Bt* cotton hybrid, intercropping, refugia, seed cotton yield

Cotton (*Gossypium hirsutum* L.), with the relatively longer life cycle (150-175 days) and its skimpy initial growth keeps the inter row space remains vacant from sowing to 60-75 days. It gives ample scope for raising short duration pulse and vegetables as intercrops. Besides supplementing to productivity/unit area and time, these intercrops serve as an insurance against menace of pests and diseases and vagaries of weather to which monocropped cotton is usually subjected to. With the introduction of *Bt* (*Bacillus thuringiensis*) cotton in India, its area continues to grow from a mere 50,000 ha in 2002, (when *Bt* cotton was first commercialized) to 8.4 million ha in 2009 represents an unprecedented 168 fold increase in eight years (Choudhary and Gaur, 2010) . *Bt* hybrids are compact and short statured (Mayee *et al.*, 2004) and thus, offers an opportunity for raising of suitable intercrop(s). Introduction of *Bt* cotton and recently released improved genotypes of pulses and vegetables provides further impetus for studying the compatibility and profitability of a *Bt* cotton based intercropping systems. When compared to normal non *Bt* cotton, *Bt* cotton could alter the pest population of cotton ecosystem and non traditional crop (such as *bhendi*) for its suitability in an intercropping with *Bt* cotton. Since most of the popular genotypes of redgram are long duration and does not fit in an intercropping, could be taken up only in strip cropping. Yet, advance short duration genotypes of redgram APK 1 (95-105 days), cowpea Co (Cp) 7, onion Co (On) 4 and *bhendi* Arke anemice, could well fit into intercropping systems. This necessitates for studying afresh the compatibility and profitability of a *Bt* cotton based intercropping systems.

Insect resistance management is very important to conserve *Bt* technology for deriving long term benefits out of it and thus, refugia system is advocated. Under the *Bt* technology guidelines, refugia crop (non *Bt* cotton) could be maintained at a minimum of 20 per cent of the planted *Bt* cotton area with the intervention of plant protection measures. Thus, under the system, a grower is forced to plant a proportion of their area under conventional cotton for refugia purpose that may incur some yield and economic loss. Hence suitable non cotton crops like redgram, cowpea and *bhendi* were proposed for testing in many situations as an alternate

Alternate host crops such as corn, soybean and sorghum provide an additional non *Bt* refugia in Argentina (Anonymous, 2007). Keeping the above in view, a study was conducted with the objective to find out the best suitable intercrop in *Bt* cotton system in addition to assessing the existing refugia system in *Bt* cotton.

MATERIALS AND METHODS

A field trial was conducted under irrigated condition at Central Institute for Cotton Research, Regional Station, Coimbatore (11°N latitude, 77°E longitude and 427.6 above mean sea level) during the winter irrigated season (August to February) of 2003-2004 and 2004-2005. The soil was clay loam in texture, low in available N (215 kg/ha), medium in available P (18 kg/ha) and high in available K (973 kg/ha) with a pH 8.7 and EC 0. 5 dS /m^2. Soil test on micronutrient showed 0.48, 1.8, 2.42, 2.80 and 0.09 ppm of DTPA extractable zinc, copper, manganese, iron and hot water extract boron, respectively. MECH 162 *Bt* hybrid was used in the study. The treatments comprised of intercropping of ridge planted *Bt* cotton with redgram APK 1, cowpea Co(Cp) 7, onion Co(On) 4 and *bhendi* Arke anemice (two rows of intercrops planted in between a pair of *Bt* cotton at 105 cm row spacing). In *Bt* cotton + 20 per cent non *Bt* system, 20 per cent non *Bt* was planted in surrounding of the plot at 90 x 60 cm spacing. Pure *Bt* cotton and pure non *Bt* cotton Bunny were also planted at 90 x 60 cm in a randomized block design with three replications. In intercropping of *Bt* cotton with redgram, cowpea, onion and *bhendi*, paired row planting of cotton at 75-105 cm x 60 cm was followed. Pure stand of intercrops were separately raised in adjacent to the experimental field to work out the indices for comparison. A basal dose of 45 kg N +19 kg P+37 kg K/ha was applied to all the treatments and 45 kg N/ha was top dressed at the time of earthing up at 45 DAS. Other cultivation practices were adopted uniformly for all the treatments.

Pre emergence application of fluchloralin @ 1 kg/ha was applied on the plots followed by two hand weedings at 30 and 60 days after sowing to keep the experimental plot weed free. Application of methyl demeton (metasystox) @ 500 ml/ha was followed at 40 and 45 DAS, respectively during 2003-2004 and 2004-2005 to contain the menace of sucking pests problem. Bollworms were controlled by using the following chemicals at single spray in *Bt* and two sprays in non *Bt* based on ETL (10% fruiting body damage). Quinalphos (ekalux) @ 1.5 l/ha (non *Bt* as first spray at 101 DAS) and indoxicarp (avaunt) @ 500 ml/ha (*Bt* as first spray at 122 DAS) and non *Bt* (as second spray at 126 DAS) were used in 2003-2004 to check the bollworms. Endosulfan (thiodan) @ 2 l/ ha (non *Bt* as first spray at 90 DAS) and indoxicarp (avaunt) @ 500 ml/ha (*Bt* as first spray at 107 DAS) and non *Bt* (as second spray at 111 DAS) were used in 2004-2005 to check the bollworms. Growth attributes, pest population, yield parameters and seed cotton yield were recorded during the course of investigation. Fibre quality parameters were analyzed. Fibre quality index (FQI= LT/vM, where L, 2.5% span length (mm), T, fibre bundle tenacity at 3.2 mm gauge (g/tex) and M, micronaire value), count (C=0.196 FQI – 16) and count strength product (CSP=1.740 FQI + 1600) were also worked out. All the quality parameters except GOT, seed index and lint index were analyzed by using high volume instruments (HVI, Statex Fibrotex model). Relative production efficiency (RPE) was calculated based on the capacity of the system for production in relation to existing system and was expressed in percentage. RPE was calculated as 'RPE = (EYD -EYE)*100/EYE, where, EYD was the equivalent yield under improved/diversified system, while EYE was the existing system yield. Relative economic efficiency (REE) was a comparative measure of economic gains over the existing system. It was expressed in percentage (REE = (DNR-ENR)*100/ENR), where DNR was the net return obtained under improved/diversified system, while ENR was net return in the existing system. Pooled analysis was made from two years data to assess the effect of intercropping on growth characters, pest population, yield attributes, yield, quality and other parameters. Benefit: cost analysis was also calculated on the basis of prevailing market price of inputs and outputs.

RESULTS AND DISCUSSION

Growth characters and yield: Intercropping systems did not influence plant growth characters, yield attributes and seed

cotton yield (Table 1). Yet, significantly lowest dry weight (685 kg/ha) was recorded with non *Bt* Bunny at 90 DAS. Diverse intercrops tried did not significantly influence growth characters and seed cotton yield of base crop of *Bt* cotton. Crop growth rate (CGR) and relative growth rate (RGR) and net assimilation rate (NAR) was calculated for the period (45-90, 91-120 DAP) did not show any marked variation amongst the system, indicating that selected intercrops did not compete with the base crop of *Bt* cotton. During the two crop growth phases of 45-90 and 91-120 DAS, respectively, CGR ranged from 1.5-2.0 to 3.0-3.7, RGR from 53.2- 64.2 to 24.7-28.8 and NAR from 0.54-0.62 to 0.45-0.57 (Table 1). Planting of the base crop and intercrops, their different growth habits, maturity periods and their peak period of growth resulted in less competition as was reflected from similar seed cotton yields. When two crops were grown together, it was imperative that the peak period of growth of the two crop species did not coincide. Cotton had also no adverse effect on yield by intercropping with cowpea and onion (Chowdhury and Singh, 1983). Besides its compact growth and its short stature (Mayee *et al.*, 2004), *Bt* cotton provided more space to intercrops for a quick growth and in turn these intercrops indirectly enabled *Bt* cotton to perform better without any competition. Thus, numerically highest seed cotton yield was recorded with *Bt* cotton + cowpea intercropping system (27q/ha) and was mainly attributed to the legume effect. Least seed cotton yield was realized with Bunny in which population of boll worms reached ETL for two times during the life cycle of the crop and subsequently controlled by chemical control measures. Thus, the yield difference observed between normal *Bt vis-à-vis* Bunny non *Bt* was explained as genetic makeup, inherent character and interaction with climatic resources that decided optimum crop growth, dry matter production and seed cotton yield. Study further revealed that significant yield differences were not evident between *Bt* cotton sole, and *Bt* + non *Bt* cotton (4:1) combination as prescribed for refugia purposes in *Bt* cotton cultivation. Effective chemical control of bollworms in non *Bt* parts of the above system helped to produce comparable seed cotton yield. The study suggested that recommended refugia planting @ 20 per cent as non *Bt* in surrounding of *Bt* cotton plot may not reduce the yield. Contrarily, Isbell, (2000) reported that protected 30 per cent refugia reduces production by 14.6 kg/ha while increasing insect control costs by US$ 8.9/ha resulting in a loss of US$ 29.8/ha in return due to adoption of refugia.

Quality parameters : Various intercropping systems tried did not influence on fibre quality parameters of *Bt* cotton. Fibre quality characters were not also adversely affected by the system of cropping (sole *versus* intercropping), since resilience genetic nature of the above parameters was not altered by these agronomic constraints. Quality being the genetic character, the response was not distinct (Bhuva *et al.*, 1995). Between MECH 162 *Bt* and Bunny, significantly higher mean values of GOT (38.2%), uniformity ratio (46.9) and micronaire (4.0) were observed with MECH 162 *Bt*. Contrarily, Bunny cotton recorded significantly higher 2.5 per cent span length of 29.1 mm. Similarly, fibre quality index, count, and count strength product were maximum with Bunny hybrid. Quality was generally decided by genetic makeup of the genotypes.

Intercrops : Intercropping of two rows of redgram, cowpea, onion and *bhendi* in between a pair of *Bt* hybrid planted in paired row planting resulted in additional yields of intercrops to the tune of 51.2 per cent (110 kg/ha), 72.1 per cent (515 kg/ha), 55.9 per cent (1,207 kg/ha) and 43.2 per cent (2,751 kg/ha), respectively of their pure stand (Table 2). Chellamuthu and Ramaswami (2000) reported that higher grain yield of black gram, greengram and cowpea might be due to its high source sink relationship in view of its short duration (65-70 days) and architecture (compact plants) that helped to exploit the sunlight for better partitioning of dry matter. Performance of the intercrops *viz.*, redgram APK 1 failed to produce additional seed yield during 2003-2004 and was mainly attributed to thermo sensitivity or poor adaptability or the combined effect of these on this genotype. Similarly, both inter and pure cropped onion produced abnormally low yield as bulb development in onion coincided with the low temperature prevailed during October. This was happened when onion intercropped with *Bt* hybrid in winter irrigated

Table 1. Plant growth characters, yield attributes and seed cotton yield of *Bt* cotton as influenced by intercropping systems (mean data of two seasons)

Intercropping systems	Height (cm)	Bolls/plant (DAS)		Dry weight (kg/ha) DAS		Burst boll/ plant	Boll weight (g)	Seed cotton yield (t/ha) Picking			CGR (DAP)		RGR (DAP)		NAR (DAP)	
		90	120	90	120			First	Second		Total		91-	45-	91-	45-
91-											90	120	90	120	90	120
Bt cotton + redgram	85.2	10.7	23.3	758	1790	24.4	4.5	12.0	07.1	19.1	1.6	3.4	63.6	28.6	0.54	0.51
Bt cotton + cowpea	83.1	7.8	24.6	958	2012	29.7	4.6	14.2	09.8	24.0	2.0	3.5	64.0	24.7	0.57	0.45
Bt cotton + onion	81.4	11.4	20.5	804	1780	26.0	4.5	13.4	08.6	22.0	1.6	3.3	56.9	26.5	0.57	0.50
Bt cotton + *bhendi*	87.1	10.1	22.6	815	1932	26.9	4.6	12.4	09.7	22.1	1.7	3.7	57.5	28.8	0.62	0.57
Bt cotton + non *Bt* cotton (4:1)	83.8	6.8	22.1	757	1661	29.5	4.5	12.9	09.8	22.7	1.5	3.0	53.2	26.2	0.57	0.47
Bt cotton (pure)	86.3	11.0	22.8	867	1916	25.4	4.5	13.2	07.5	20.7	1.8	3.5	64.1	26.4	0.62	0.51
Non *Bt* cotton (pure)	79.3	3.8,	13.4	685	1303	25.2	4.6	11.2	08.8	20.0	1.4	2.1	62.9	21.5	0.69	0.44
SEd±	6.7	2.8	4.1	82	269	2.8	0.1	01.9	02.6	02.3						
CD(p=0.05)	NS	NS	NS	250	NS	NS	NS	NS	NS	NS						

Table 2. Economics and growth analysis of *Bt* cotton as influenced by intercropping systems (mean data of two seasons)

Intercropping system	Intercrop yield (kg/ha)	Cost of cultivation ($x10^3$ Rs/ha)	Gross return ($x10^3$ Rs/ha)	Net Return ($x10^3$ Rs/ha)	B:C ratio	LER	Total yield (q/ha)	IER	CP (Rs/ha/ day)	RPE (%)	REE (%)
Bt cotton + redgram	110 (215)	28.05	52.52	24.47	0.9	1.44	2.01	1.48	163	-2.9	-9.3
Bt cotton + cowpea	515(714)	28.85	70.60	41.75	1.5	1.88	2.70	1.71	278	30.5	54.7
Bt cotton + onion	1207(2158)	31.85	65.21	33.36	1.1	1.62	2.51	1.43	222	21.3	23.6
Bt cotton + *bhendi*	2757(6368)	32.16	81.88	49.72	1.6	1.51	3.16	1.55	331	53.0	84.2
Bt cotton + non *Bt* cotton (4:1)	-	26.90	58.93	32.08	1.2	1.10	2.27	1.10	214	9.9	18.9
Bt cotton (pure)	-	26.85	53.84	26.99	1.0	-	2.07		180	0.00	0.00
Non *Bt* cotton (pure)	-	27.85	51.95	24.10	0.9	-	2.00		161	-3.2	-10.7

Values in parentheses are pure crop yield

season (August –February) in southern cotton zone. However, the same off season favoured higher market price and premium to onion.

Genetic inbuilt resistance in *Bt* cotton to bollworms complemented with imidacloprid treated seed for initial sucking pest prevention led to least number of spray (a cost cutting exercise) required in *Bt* cotton cultivation. This situation might further encourage growing of vegetables (*bhendi*) with less spray drift in an intercropping system involving *Bt* hybrids. The study further suggested that *bhendi* and redgram could be taken up as intercrops for extra yield and income with *Bt* hybrid without reducing seed cotton yield. Thus, redgram and *bhendi* could be further tested for its suitability as an alternate refugia strategy in *Bt* cotton cultivation. In similar line, planting of *Bt* cotton in 80 per cent area and allotting of remaining 20 per cent to marigold/okra chickpea was recommended as an alternate strategy for refugia (non *Bt* and non cotton) management in *Bt* cotton at Dharwad.

Pest population : Sucking pest population and bollworm percentage (fruiting body damage) were recorded in different intercropping systems. The population of whitely, aphids and jassid were counted below ETL at 30 DAS in both years. The mean/plant population of whitefly ranged from 1.86 to 2.46, aphid from 3.53 to 6.16 and jassid from 2.45 to 3.83 were recorded with different systems. However, significantly least mean population/plant of 1.86, 3.53 and 2.45 whitefly, aphid and jassid, respectively were counted with *Bt* cotton + cowpea intercropping system. Natarajan and Seshadri (1988) concluded that lower aphid population was recorded in cotton cowpea system than cotton sole crop. Bollworms reached ETL (10% fruiting body damage) in non *Bt* hybrid (Bunny and 20 per cent in non *Bt*, in *Bt* + 20 per cent non *Bt* in two times at 101 and 126 DAS in the year of 2003-2004 and 90 and 111 DAS in 2004-2005 and controlled by the recommended methods. However, the bollworm also crossed the ETL in *Bt* in single time at 122 and 107 days respectively during 2003-2004 and 2004-2005 in all the systems as *Bt* hybrid is the base crop and effectively checked. Intercropping of *bhendi*, onion, cowpea, redgram, and 20 per cent non *Bt* had not significantly influenced the bollworms percentage.

Economics : Intercropping systems resulted in higher net return as compared to sole cotton (Table 2). This might be due to higher monetary return from seed cotton and respective intercrops obtained under these intercropping systems. Variation in net return in a cotton production system was a function of yields, prices of the commodities and of course, cultivation cost. What distinguished intercropping system from monoculture was the introduction of several components into the income calculation, such as, relative price of two or more commodities, efficiency of production that resulted in lower production cost, and compensation between the two or more intercrop components. As it was less likely that prices of several crops will go down between planting and harvest than that might occur with a single crop, thus the diverse mix of enterprises would provide higher income than any single crop.

Economic returns obtained from intercrops calculated that amongst the intercrops, *bhendi* registered the highest net return (Rs. 16,692/ha) followed by cowpea (Rs. 8,805/ha). Amongst the intercropping system the highest net return (Rs. 49,718/ha) and benefit cost ratio (1.6) were recorded with *Bt* cotton + *bhendi* system (Table 2). Besides BCR, intercropping of *bhendi* with *Bt* hybrid produced the highest seed cotton equivalent yield (31.6 q/ha), crop profitability (Rs. 331/ha/day), relative production (53.0) and economic efficiency (84.2) of the system. The increase in seed cotton yield equivalent was due to higher additional yield and market price for intercrops. However, the LER (1.88) and IER (1.71) were maximum with intercropping of *Bt* cotton with cowpea, might be due to higher realization of 72.1 per cent of pure crop yield influenced the above index in favour. Chelliah and Gopalaswamy (2000) reported that effective land use efficiency as reflected by higher land equivalent ratio and both were higher in the intercropping systems.

Thus, the study suggested that *Bt* cotton intercropped with *bhendi* was most profitable. Further, recommended refugia planting @ 20 per cent of non *Bt* as surrounding of *Bt* cotton plot may not reduce the yield. Yet, intercropping of short duration crop like redgram and *bhendi* may

be promoted for its suitability as non *Bt*/non cotton refugia in *Bt* cotton cultivation.

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