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Improving the fertilizer use efficiency and profitability of small farms by intercropping with transgenic Bt cotton

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Bt transgenic hybrid cotton productivity and profitability could not be sustained after 2007 in India which necessitated to investigate into the nutrient needs of transgenic Bt hybrid cotton and their intercropping systems. Seven Bt transgenic hybrid cotton intercropping systems with four fertilizer management practices and two plant spacings were evaluated in split plot design during 2010-12 in *Vertisols* at Central institute for Cotton Research, Nagpur, India. Present recommendation of Pigeon pea *refugea* as stripcropping (2:8) with transgenic Bt hybrid cotton reduced seed cotton yield by 69%, therefore, not accepted by 82% farmers. *Tagetus sp*. or *Dolichus lab lab* were advocated as better *refugea* with economic advantage of US $ 600 ha-1 with C: B ratio of 1:2.8. However, a net a profitability of US $768 and 662 ha-1 with a C:B ratio of 1:3.7 and 1:3 were achieved in intercropping with roselle or soybean compared to US $ 348 C:B ratio of 1:2.5 only with transgenic Bt hybrid cotton alone. This study also breaks the myth of 30% extra fertilizer dose for transgenic Bt hybrid cotton, which requires 90:20:37 N:P:K kgha-1 only and soybean intercropping requires additional 14:13:0 N:P:K kg ha-1. Any deficiencies arising can be economically corrected with two prophylactic foliar sprays of NMgB after square initiation. NPK uptake, nutrient and fertilizer use efficiencies were significantly improved in transgenic Bt hybrid cotton and intercropping with soybean and roselle (except PUE). Hand weeding cost was minimum in soybean and maximum in roselle with Pendimethalin PPI rotated with Pyrithiobac Na EPE.

Key words: *Transgenic* Bt hybrid cotton, fertilizer use efficiency, intercropping, small farms, soybean.

INTRODUCTION

Small and marginal (1.6 ha) rainfed cotton farmers (58%) invested US $ 80 ha[1] on transgenic cotton seeds with double fertilizer dose and improved the productivity, which could not be sustained after 2008 necessitated this study to investigate into the nutrient needs of transgenic Bt hybrid cotton and intercropping systems for better

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profitability. Seedling droughts followed by excess rains during 2008 to 2014 reduced transgenic Bt cotton production, productivity and total factor productivity and profitability despite of increased fertilizer consumption (Anonymous, 2013; CCI, 2013; FAI, 2008, 2012; Raju and Thakare, 2013, Reddy et al., 2012). Transgenic Bt hybrid cotton cultivation is the livelihood for 4.0 million small and marginal farmers who grow it on 6.5 million ha area, with a cash input costs of US $ 235 ha^{-1} gives a net profitability of US $ 612 ha^{-1} with a C:B ratio 1:3.6. Transgenic Bt hybrid cotton is annually rotated with soybean-chickpea, gives a profitability of US $ 893 ha^{-1} with C:B ratio of 1:4.8. Heavy and extended monsoon rains causes severe weed infestation in the absence of pre and post emergence herbicide use causing serious crop losses. Although, sequential chickpea crop could recover some crop losses with this excess rains, abuse of tractors for seed bed preparation and planting is compacting the soils with restricted root growth in rotational transgenic Bt hybrid cotton (Venugopalan, 2009). Soybean-chickpea production and productivities are not as per national demand and there is limited scope for increasing area except intercropping. The income generated by the present rainfed transgenic Bt cotton based sequential cropping systems is insufficient to get a fairly good standard of living for Indian rainfed farmers who requires atleast US $ 1000 ha^{-1} which is possible only through integrated farming systems (IFS) mode. Diversified intercropping systems (Asewar et al., 2008; Seran and Brintha, 2011; Raju and Thakare, 2013) along with boundary cultivation with arid horticulture/ forest tree species such as teak/red sandal, silvi-pastoral systems dairy and small ruminants could avert this risk to some extent, improve profitability and sustainability of transgenic Bt hybrid cotton farming by preventing leaching, runoff, soil erosion losses and better interception of rainfall. Transgenic Bt hybrid cotton based inter cropping systems were identified across the country during 2007, 2008, 2009 seasons under ICAR funded Technology Mission on Cotton (TMC) Mini Mission-I programme (Raju and Thakare, 2013). Transgenic Bt hybrid cotton + marigold intercropping system produced 0.4 t ha^{-1} more seed cotton yield than pigeon pea /non transgenic Bt cotton as *refugea* (Yenagi et al., 2011). Transgenic Bt hybrid cotton requires 100% RDF only with 29% improvement in cotton equivalent yield (CEY) in *Vertisols* (Rekha and Dhurua, 2010). Transgenic Bt hybrid cotton + soybean had maximum predators (Mote et al., 2001). Intercropped maize reduced pink boll worm damage in cotton (Kavitha et al., 2003; Seran and Brintha, 2010). Indian cotton consumes 3.5% of the total fertilizers with Fertilizer Use Efficiency (FUE) of 9.6 kg^{-1} seed cotton kg^{-1} fertilizers applied. Transgenic Bt hybrid cotton in central India is advocated to fertilize with 90:24:37 NPK kg ha^{-1} and micronutrients mixtures as soil and foliar application with a productivity of 0.5 Mg lint ha^{-1} and FUE of 7.0 kg^{-1} seed cotton kg^{-1} fertilizers applied.

Transgenic Bt hybrid cotton sample surveys found fertilizer application rate was doubled with the introduction of transgenic Bt cotton, which was clearly reflected in all India fertilizer consumption pattern (FAI, 2008, 2012; Reddy et al., 2012). However, after 2008-2012 there is a decline in factor productivity despite of increased fertilizer consumption necessitated to find out any secondary and micronutrient deficiencies arising. Soybean-transgenic Bt hybrid cotton is grown on residual fertility in central India with a productivity of 1.5 and 2.0 Mg ha^{-1} without and with fertilizers respectively. Excess fertilizers to cotton fields under saturated conditions lose 18-24 kg N ha^{-1} beyond root zone, which can be trapped, if intercropped. Sub optimal soil fertilization with foliar application of urea improved 16 to 29% seed cotton yields, however, less cost-effective than carefully planned, demand driven, timely soil-applied fertilizers (Wiedenfield et al., 2009). Calcareous soils and droughts reduce the soil availability of Zn and B. Foliar applied B at 0.2 kg ha^{-1} boric acid and Na tetra Borate, increased B concentration 8 to 11 mg kg^{-l} and 16 to 22 mg kg^{-l} respectively in cotton and soybean. Looking into increased fertilizer application/ prices in rainfed transgenic Bt hybrid cotton in India without improving productivity necessitated comprehensive validation of nutrient requirements and recommendations for enhanced FUE and profitability.

MATERIALS AND METHODS

Soil and climate of the experimental site

Experimental site was mild sloppy, medium deep *Vertisol*, Nagpur, India (21°09'N 79°09'E, altitude 331 MSL). Nagpur is located at the centre of Indian peninsula, has a tropical wet and dry climate (Köppen climate classification Aw) with dry conditions prevailing for most of the year. It receives on an average 852 mm rainfall in 48 rainy days during June to October months. However, fluctuations in the onset of monsoon rains resulted in seedling droughts of 14-29 days were most common change in the climatic features of this area. Soil analysis of experimental site observed, soil depth as 1.2 m, soil textural class clay loam, pH 8.1, organic carbon 0.45%, available N:P:K 280:6.5:249 kg ha^{-1}. DTPA extractable Zn 0.7 ppm, Mn 2.54 ppm and B 0.1 ppm. Transgenic Bt hybrid cotton is planted in 45 and 52% on shallow and medium deep *Vertisols* in central India. Farmers plant 80% cotton area as dry sowing with pre monsoon showers between 25-29th June without any pre emergence herbicides. Post emergence herbicides are being accepted by 35% of the cotton farmers during excess rains, where controlling weeds by conventional systems will be very difficult in the absence of timely intercultures and hand weedings.

Seasonal rainfall during 2010, 2011 were 1032 and 832 mm both the years received excess rains in July, August September months. Seedling droughts followed by excess rains in few rainy days became common feature of climate change with no rains June 20-30th during 2010 year adversely affected germination, but during 2011 year received no effective rains upto 24th June-14th.July and 24th July to 4th, August seedling drought received only 54.3% rains at the end of the month without any rain during October month.

A field experiment was conducted in *Vertisols* with six transgenic Bt hybrid cotton based intercropping systems in main plots with four nutrient management modules in sub plots at two transgenic Bt

hybrid cotton spacings 90 x 45/ 30 cm as sub sub plots in split plot design with four replications during 2010, 2011 monsoon seasons. Cropping system were: C_1: Paired row *transgenic Bt* hybrid cotton with Cry 1Ac' MRC 6301' (PR 90/135 cm); C_2: *Transgenic* Bt hybrid cotton + pigeon pea *Maruti* (90 x 45 cm) with 4:4.4:0, C_3: C_1 + soybean 'JS-335' (45 x 10 cm) with 14:13:0, C_4: C_1+ shrub field bean 'Ankur Goldy'(45 x 10 cm) with 30:11:10, C_5: C_1 + marigold 'African tall'(45 x 22.5) with 80:35:67, C_6: C_1 + maize '*Komal*'(45 x 22.5 cm) with 48:11:10, C_7: C_1+ roselle 'local' (45 x 10 cm) with 20:9:7; C_8: C_1+ castor 'TAU-9 (45 x 22.5cm) with 24:7:0 kg ha^{-1} N: P: K respectively. Transgenic Bt hybrid cotton received a fertilizer dose of F_1: 90:20:37 + 2% Urea + 0.2% Mg + 0.06% B foliar spray twice at squaring to flowering stage; F_2: 90:20:37+5 kg Mg+2 kg B ha^{-1} as soil application at the time of sowing; F_3: 113:24:47 + 2% Urea +0.2% Mg + 0.06% B foliar spray twice at squaring to flowering stage; F_4: 113:24:47+5 kg Mg + 2 kg B ha^{-1} as soil application at the time of sowing. N fertilizers were applied in 3 equal splits at 20, 45, 65 days after sowing (DAS). Foliar correction of nutrients were made 75 and 90 DAS. Rotation of herbicides Pendimethalin 1.0 kg PPI and Pyrithiobac Na 0.035 kg a.i. ha^{-1} early post emergence applications were made respectively in 2010 and 2011 years along with two intercultures at 21 and 42 DAS followed by one hand weeding to remove uncontrolled/ resistant weeds.

METHODOLOGY

Experiment was planted when a cumulative rainfall of 150 mm was received that is, 24th, June in *Vertisol* in all the years on the same site with same randomization. Fertilizer was applied to transgenic Bt hybrid cotton paired rows as per the fertilizer treatments made in addition to proportion to the intercrop population with respective intercrops recommended dose of fertilizers. In order to use the existing hoes, only two rows of intercrops were accommodated in between two paired rows. Conservation furrows were opened to conserve runoff and provide drainage at every wide spaced transgenic Bt hybrid cotton row. Popular five tyned soybean marker (*datari*) was used for planting intercrops 45 cm a part, where 1st two rows were drilled with intercrop seed and subsequent two rows of cotton were dibbled leaving centre row blank, like this 4 sets were made in each plot (9 x 4.5 m). Soil moisture was measured by oven dry method at harvest. Economic yield, fresh and dry weights, biomass, nutrient uptake were estimated and analyzed with SAS 9.3 statistical package. Marigold flowers were harvested a day before the major Indian festivals starting from birth day of Indian elephant faced god (19th September) to festival of lamps (11th November) when farmers get double the price 0.80 US $ kg^{-1} fresh flowers compared to half in normal days and remaining left for next year seed production after mid November. Price of cotton US $ 0.83 kg^{-1}, field bean US $ 0.17 kg^{-1}, soybean US $ 42 Mg^{-1}, pigeon pea and castor US $75 Mg^{-1}, maize green cob US $ 22 Mg^{-1}, field bean US $ 167 Mg^{-1}, marigold 330 Mg^{-1}, Pendimethalin US $ 15 ha^{-1}, Pyrithionbac Na US $ 28 ha^{-1}, intercultures US $ 3 ha^{-1}, weeders US $ 0.17 h^{-1}, harvesting charges US $ 8.3 Mg^{-1} fertilizer N US$ 167, 467, 167 Mg^{-1} for NPK were considered calculating cost of cultivation and profitability.

RESULTS AND DISCUSSION

Yield performance of intercropping systems

Transgenic Bt hybrid cotton + soybean intercropping system was at par with transgenic Bt hybrid cotton + marigold intercropping system with 89 and 65% higher cotton equivalent yield (CEY) and also significantly higher CEY than with field bean intercropping system which produced 44% more CEY over paired row (PR) transgenic Bt hybrid cotton (Table 1). Transgenic Bt hybrid cotton + roselle significantly improved CEY by 111% and at par with soybean intercropping system with CEY of 89% over PR transgenic Bt hybrid cotton (Figure 1).

Uptake, use efficiencies

NPK uptake and FUE were significantly improved in both PR transgenic Bt hybrid cotton and transgenic Bt hybrid cotton + soybean intercropping system. NPK uptake, NUE, KUE, NPK FUE of the Transgenic Bt hybrid cotton + roselle / marigold intercropping systems was also significantly improved over PR transgenic Bt hybrid cotton. NPK uptake was significantly improved in transgenic Bt hybrid cotton + maize intercropping system but non significantly improved Nutrient and FUE. Fertilizer dose of 90:20:37 N:P:K kg ha^{-1} 2% Urea+ 0.2% Mg+0.06% B at squaring to flowering period also produced significantly superior and similar NPK uptake in both transgenic Bt hybrid cotton and intercropping systems FUE to that of 113:24:47 N:P:K kg ha^{-1} alongwith 5 kg Mg + 2 kg B ha^{-1} soil application at the time of sowing (Table 2).

Profitability

Transgenic Bt hybrid cotton intercropped with roselle and soybean produced statistically similar profitability of US $ 768 and 662 ha^{-1} with a C:B ratio of 1: 3.73 and 1: 2.99 respectively (Table 3). However, determinate transgenic Bt hybrid cotton + indeterminate type pigeon pea strip cropping put to 69% losses due to severe irrecoverable competition. Foliar correction of nutrient deficiencies in both excess and scanty rainfall conditions by 2% Urea + 0.2% Mg +0.06% B at squaring to flowering period is significantly superior over soil application at the time of sowing at 5 kg Mg+ 2 kg B ha^{-1} with only 90:20:37 N:P:K kg ha^{-1} which was statistically similar to that of higher doses presently recommended for transgenic Bt hybrid cotton 113:24:47 N:P:K kg ha^{-1}.

Root growth, soil moisture extraction and senescence

Transgenic Bt hybrid cotton MRC 6301 had produced shallow (Table 4) tap and main lateral roots (<30 cm). Selection of ever green leaf color in transgenic Bt hybrid cotton MRC 6301 masked nutrient deficiencies by shortage fertilizer nutrient supply or inter plant competition. Significantly more nutrient deficient cotton leaves/plant were observed due to intercropping with

Table 1. Mean performance of transgenic Bt hybrid cotton based intercropping systems.

Treatment	Seed cotton yield t ha^{-1}	Intercrop yield t ha^{-1}	CEY t ha^{-1}	BMP cotton t ha^{-1}	BMP inter crop t ha^{-1}	HI of Bt cotton	HI of intercrop
PR Transgenic Bt hybrid cotton	0.9		0.9	2.86		33	
Bt hybrid cotton+pigeon pea 8:2	0.4	0.18	0.6	3.27	1.66	15	13.1
Bt hybrid cotton+ soybean 2:2	1.2	0.64	1.7	3.15	1.47	38	42.8
Bt hybrid cotton+ field bean 2:2	1.2	0.32	1.3	3.49	0.43	33	52.9
Bt hybrid cotton+ marigold 2:2	1.2	1.34	1.9	3.00	1.07	39	86.1
Bt hybrid cotton+ maize 2:2	1.1		1.1	3.39		31	
Bt hybrid cotton+ roselle 2:2	1.1	0.14	1.7	2.99	2.03	37	7.6
Bt hybrid cotton+ castor 2:2	1.1	0.09	1.1	3.25	0.20	31	49.9
SE±5%				0.35			
CD±5%	0.2	0.19	0.2		0.33	7	5.6
F1: 90:20:37 N:P:K kg ha^{-1} 2%Urea+0.2%Mg+0.06% B	1.0	0.41	1.3	3.15	1.07	33	41.3
F2: 90:20:37 N:P:K kg ha^{-1} alongwith 5 kg Mg + 2 kg B ha^{-1}	1.0	0.39	1.2	3.13	1.06	31	42.1
F3: 113:24:47 N:P:K kg ha^{-1} 2% Urea+0.2%Mg+ 0.06% B twice	1.0	0.50	1.3	3.08	1.23	33	42.1
F4: 113:24:47 N:P:K kg ha^{-1} alongwith 5 kg Mg + 2 kg B ha^{-1}	1.1	0.50	1.3	3.34	1.20	32	42.3
SE±5%		0.05		0.12		1	2.0
CD±5%	0.1		0.1		0.12		
90 x 45cm	0.9	0.40	1.2	2.68	1.17	35	41.7
90 x 30cm	1.1	0.50	1.4	3.67	1.11	30	42.5
SE±5%	0.0				0.06		1.2
CD±5%		0.03	0.0	0.13		1	

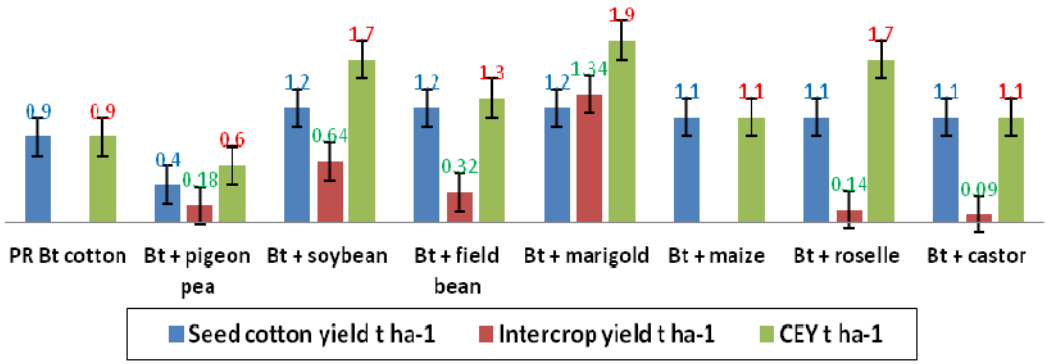

Figure 1. Cotton based intercropping systems.

Table 2. Nutrient uptake, use efficiencies as influenced by intercropping systems.

Treatment	Bt hybrid cotton									Intercrop			Bt hybrid cotton intercropping system								
	Uptake			NUE			FUE			Uptake			Uptake			NUE			FUE		
Cropping systems	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
PR Bt hybrid cotton	44	7	11	22	144	89	10	21	21				44	7	11	22	144	89	10	21	21
Bt hybrid cotton+ pigeon pea 8:2	22	3	5	20	168	93	5	9	9	26	11	17	67	25	33	24	179	101	8	18	9
Bt hybrid cotton+ soybean 2:2	59	9	15	21	150	83	13	26	26	32	10	14	89	17	26	42	228	138	22	48	26
Bt hybrid cotton+ field bean 2:2	56	8	13	22	161	91	13	27	27	43	15	19	81	15	26	35	209	119	18	32	27
Bt hybrid cotton+ marigold 2:2	62	8	12	20	152	100	13	27	27	26	10	14	129	23	34	40	243	162	20	34	34
Bt hybrid cotton+ maize 2:2	50	7	12	22	154	91	12	23	23	24	8	11	69	17	26	22	154	91	12	23	23
Bt hybrid cotton+ roselle 2:2	52	8	12	22	142	90	12	24	24	38	11	18	76	17	28	25	151	96	14	26	28
Bt hybrid cotton+ castor 2:2	52	8	13	21	141	82	12	24	24	31	10	15	60	12	17	27	158	96	12	25	24
SE±5%					18					12	3	4									
CD±5%	10	2	2	1		6	2	4	4				14	4.2	5	2	40	7	2	5	4
F1: 90:20:37 N:P:K kg ha^{-1} 2%Urea+0.2%Mg+0.06% B	51	7.4	12	21	155	88.2	12	23	23.4	31	10	15	77	17	25	29	187	110	15	29	25
F2: 90:20:37 N:P:K kg ha^{-1} alongwith 5 kg Mg + 2 kg B ha^{-1}	47	6.8	11	21	154	92	11	22	21.6	35	13	17	73	16	24	29	185	113	14	27	23
F3: 113:24:47 N:P:K kg ha^{-1} 2%Urea+0.2%Mg+ 0.06% B twice	49	7.3	11	21	146	88.8	11	22	22.3	28	10	14	78	17	25	29	178	111	15	28	24
F4: 113:24:47 N:P:K kg ha^{-1} alongwith 5 kg Mg + 2 kg B ha^{-1}	51	7.5	12	21	151	90.9	12	23	23.4	33	10	15	79	17	25	30	183	113	15	29	25
SE±5%	1.8	0.4		0.5	7.13	2.11				3.1	1	1	3.4	0.8	0.9	1	7	3		1	
CD±5%			0.9				1	1	1.49										1		2
90 × 45 cm	47	7	11	21	151	89.6	11	22	21.6	33	11	16	73	16	24	29	183	111	14	27	23
90 × 30 cm	52	7.5	12	21	152	90.3	12	24	23.7	30	10	15	81	17	26	29	183	112	15	30	25
SE±5%		0.3		0.3	5.22	1.37				2.3	1	1		0.8	1	0	6	2			
CD±5%	1.7		0.4				0	1	0.69				2.4						0	1	1

soybean, marigold, maize and castor, which were although not at economic threshold level compared to NCS 145 Bunny transgenic Bt hybrid cotton (Table 4). These intercroppings except maize also registered significantly lowest sucking insect and foliar diseases damage compared to sole cotton.

Fibre quality

Fibre quality was almost unaffected by droughts during seedling or termination and excess rains received during 2010 and 2011 respectively. Weaker fibres were produced by intercropping with field bean during 2011 drought year and fibre strength was improved by closer plant spacings due to non uniform fibres under excess rains of 2010 (Table 5).

Weed incidence

Lowest hand weeding cost was registered with castor /maize followed by close grown legume intercropping with soybean and field bean to maximum in sole cotton / pigeon pea strip cropping and roselle/marigold intercropping (Table 6). Castor and maize intercrops were very sensitive at young seedling stage to Pyrithiobac Na needs delayed application or directed sprays.

Herbicide tolerant weeds

Pyrithiobac Na at 0.035 kg a.i.ha^{-1} could not effectively controlled grasses(6.1 M^2) such as *Cynodon doctylon, Cyperus rotundus, Sorghum halepense, Eriochloa Polystachia, Commelina benghalensis* and broad leaved weeds (13.8 M^2) such as *Tridax procumbence, Phylanthus niruri, Parthenium hysterophorus, Merremia emarginta,*

Table 3. Profitability of transgenic Bt hybrid cotton based intercropping systems.

Treatment	Bt hybrid cotton economics US $				Intercrop economics US $			Cropping system economics US $			
Cropping systems	Gross returns	Cost of cultivation	Net returns	BCR	Gross returns	Cost of cultivation	Net returns	Gross returns	Cost of cultivation	Net returns	BCR
PR Bt hybrid cotton	600	233	367	2.50				600	233	358	2.49
Bt hybrid cotton+ pigeon pea 8:2	267	233	33	1.15	98	21	77	367	250	110	1.42
Bt hybrid cotton+ soybean 2:2	750	250	500	3.04	241	85	156	1000	333	662	2.99
Bt hybrid cotton+ field bean 2:2	767	250	517	3.03	54	34	20	817	283	532	2.87
Bt hybrid cotton+ marigold 2:2	767	250	517	3.08	156	83	74	917	333	592	2.79
Bt hybrid cotton+ maize 2:2	667	233	433	2.77	0	0	0	683	250	427	2.67
Bt hybrid cotton+ roselle 2:2	683	250	450	2.80	359	37	322	1050	283	768	3.73
Bt hybrid cotton+ castor 2:2	667	233	433	2.77	54	18	37	733	267	467	2.79
CD±5%	117	8	117	0.42	30	10	22	127	12	118	0.39
F1: 90:20:37 N:P:K kg ha^{-1} 2%Urea+0.2%Mg+0.06% B	650	250	417	2.69	152	44	108	767	283	496	2.76
F2: 90:20:37 N:P:K kg ha^{-1} alongwith 5 kg Mg + 2 kg B ha^{-1}	600	233	367	2.49	159	43	116	717	267	451	2.60
F3: 113:24:47 N:P:K kg ha^{-1} 2%Urea+0.2%Mg+ 0.06% B twice	650	250	400	2.64	170	49	121	767	283	494	2.72
F4: 113:24:47 N:P:K kg ha^{-1} alongwith 5 kg Mg + 2 kg B ha^{-1}	683	250	433	2.75	161	48	113	800	283	518	2.79
SE±5%		2			10	3	9				
CD±5%	33		38	0.15				46	7	43	0.14
90×45	600	233	367	2.61	152	44	109	717	267	451	2.69
90×30	700	250	433	2.68	169	49	120	817	300	529	2.74
SE±5%			17	0.06			7				0.05
CD±5%	17	2			8	2		18	2	17	

Digera arvensis, Acalypha india and Desmodium sp. Similarly, Pendimethalin at 1.0 kg a.i.ha^{-1} PPI continuous use could not controlled *Echinocloa crussgalli*. This resulted for requirement for hand weeding or graminicides besides interculture operations (Table 6).

DISCUSSION

Scope for commercial intercropping

Farmer's acceptance of intercropping is limited to poor awareness difficulty in interculture operations and weed management within row except by tribes for food security in India. Yield stagnation in cotton, soybean crops, risk associated with changing climate, price fluctuations and benefit from residual fertility can be dealt with better profitability and solutions for difficulties in intercropping adoption. Transgenic Bt hybrid cotton and soybean is cultivated in 6.87 and 9.0 million ha respectively with 1.0 t ha^{-1} productivity in Madhya Pradesh, Maharashtra and Andhra Pradesh states of central India (CCI, 2013), which can be brought under transgenic Bt hybrid cotton +soybean intercropping with improvement of 89% in CEY. This requires targeted efforts with wide scale demonstrations from public sector and soya processors extension. These results were in agreement with those observed by Raju and Thakare (2013).

Risk prone areas

Roselle and marigold intercropping will be suitable for low and high rainfall districts with sloppy terrains respectively. Both were suitable in IPM as

Table 4. Root growth and soil moisture extraction during drought year 2011-2012.

Treatment	Lateral root spread cm		Soil moisture content and use			Red color leaves%		
Cropping systems	Cotton	Intercrop	20 cm	40 cm	cm	Disease	Insect	Nutritional
PR Bt hybrid cotton	23.6		9.5	10.5	54.3	1.19	1.4	1.23
Bt hybrid cotton+ pigeon pea 8:2	20.4	50.9				1.58	1.7	1.49
Bt hybrid cotton+ soybean 2:2	24.3	17.0	6.2	6.8	63.3	0.71	0.7	2.27
Bt hybrid cotton+ field bean 2:2	17.8	35.4	9.0	10.7	54.8	1.15	1.4	1.27
Bt hybrid cotton+ marigold 2:2	24.4	22.3	7.6	9.4	58.5	0.59	0.9	2.21
Transgenic Bt hybrid cotton+ maize 2:2	17.3	18.5	4.2	7.3	66.0	1.01	0.9	2.53
Bt hybrid cotton+ roselle 2:2	24.1	74.5	9.0	11.0	54.7	1.14	1.5	1.39
Bt hybrid cotton+ castor 2:2	24.0	33.7	9.8	11.0	54.0	0.78	0.8	2.61
SE±5%	2.6							
CD±5%		7.4	0.9	1.87	2.04	0.51	0.6	0.84
F1: 90:20:37 N:P:K kg ha^{-1} 2% Urea+0.2%Mg+0.06% B	23.5	29.2	7.9	9.3	58.0	1.05	1.0	1.92
F2: 90:20:37 N:P:K kg ha^{-1} alongwith 5 kg Mg + 2 kg B ha^{-1}	20.8	31.3	8.0	9.6	57.9	1.02	1.2	1.84
F3: 113:24:47 N:P:K kg ha^{-1} 2% Urea+0.2%Mg+ 0.06% B twice	22.2	28.3	7.7	9.6	58.1	0.94	1.2	2.14
F4: 113:24:47 N:P:K kg ha^{-1} alongwith 5 kg Mg + 2 kg B ha^{-1}	21.5	28.9	7.9	9.5	57.7	1.05	1.2	1.60
SE±5%		1.8	0.5	0.59	1.28	0.15	0.1	0.33
CD±5%	1.7							
90×45 cm	21.9	31.5	8.0	9.3	58.0	0.99	1.1	1.90
90×30 cm	22.1	27.3	7.8	9.7	57.8	1.05	1.2	1.85
SE±5%	0.5		0.3	0.47	0.82	0.10	0.1	0.13

former reduces damage of sucking pests and later for bollworms acts as *refugea* at least in around largely populated *peri* urban areas for the supply of Iron rich fresh green leafy vegetable and fresh flowers in premium price early season. These results were in agreement with those observed by Raju and Thakare (2012).

Intercrops with suitable modifications

Hybrid maize for green cobs / fodder and castor TAU-9 variety both were able to improve CEY by 22%, which needs suitable genotype selection at optimum spacing under the umbrella of growth regulators. Hybrid maize in transgenic Bt hybrid cotton intercropping system is excellent soil binding intercrop after harvest winter pulses can also be drilled with residual soil moisture for *refugea* requirement for both *Helicoverpa armigera* and *Pectinophora gossypiella*. Transgenic Bt hybrid cotton with castor hybrid as a relay intercrop in high rainfall areas and stripcropping in low rainfall areas can be exploited as it can be planted after receding rains in mid September in order to avoid competition with early transgenic Bt hybrid cotton vegetative growth on residual moisture (Raju et al., 2012).

Fertilizer for intercropping

A fertilizer dose of 90:20:37 N:P:K kg ha^{-1} with foliar correction of nutrient deficiencies by 2%Urea for N, 0.2%Mg for Mg, 0.06% B for Boron deficiency is sufficient as those observed by Raju and Thakare (2012). There is no need of higher nutrients for determinate type transgenic Bt hybrid cottons with shallow root system of synchronous flowering with early retention of fruiting bodies. Separate fertilizer application to drill sown intercrops proportion to their population are to be drilled as the pit method of NPK fertilizer placement cannot be shared by 45 cm away

Table 5. Fibre quality during experimentation.

Treatment	2.5% span length		Uniformity ratio%		Micro naire		Strength g/tex	
Cropping systems	2010	2011	2010	2011	2010	2011	2010	2011
PR Bt hybrid cotton	29.3	29.1	48.3	46.6	3.7	3.13	21.0	23.0
Bt hybrid cotton+ pigeon pea 8:2	30.1	28.6	48.6	46.6	4.0	3.13	21.2	22.2
Bt hybrid cotton+ soybean 2:2	30.2	28.4	49.7	46.6	4.0	3.30	20.6	22.3
Bt hybrid cotton+ field bean 2:2	29.6	27.5	48.9	46.8	3.9	3.18	20.7	20.8
Bt hybrid cotton+ marigold 2:2	30.0	28.7	48.5	47.1	3.9	3.30	21.1	22.2
Bt hybrid cotton+ maize 2:2	29.9	28.7	49.0	47.1	4.1	3.30	20.3	22.5
Bt hybrid cotton+ roselle 2:2	29.7	29.6	48.5	45.8	3.9	3.33	21.2	23.5
Bt hybrid cotton+ castor 2:2	30.1	29.2	48.8	46.8	4.1	3.50	21.0	22.4
SE±5%	0.62	0.6	0.68	0.4	0.2	0.12	0.37	
CD±5%								1.03
F1: 90:20:37 N:P:K kg ha^{-1} 2% Urea+0.2%Mg+0.06% B	29.9	28.7	48.8	46.8	3.9	3.26	20.8	22.4
F2: 90:20:37 N:P:K kg ha^{-1} alongwith 5 kg Mg + 2 kg B ha^{-1}	29.6	28.7	48.5	46.6	4.0	3.28	20.9	22.3
F3: 113:24:47 N:P:K kg ha^{-1} 2% Urea+0.2%Mg+ 0.06% B twice	30.0	28.6	48.9	46.7	3.9	3.25	20.8	22.4
F4: 113:24:47 N:P:K kg ha^{-1} alongwith 5 kg Mg + 2 kg B ha^{-1}	30.0	28.8	48.9	46.6	3.9	3.26	21.1	22.5
SE±5%	0.1	0.1	0.3	0.20	0.04	0.05	0.2	0.21
90 × 45 cm	30.0	28.7	49.0	46.6	4.0	3.25	20.7	22.5
90 × 30 cm	29.8	28.7	48.6	46.8	3.9	3.27	21.1	22.4
SE±5%	0.1	0.1		0.1	0.03	0.02		0.08
CD±5%			0.3				0.3	

Table 6. Hand weeding cost incurred with Pyrithiobac Na used during 2011.

Treatment	Hand weeding costs after Pyrithiobac Na application US $ m^2 22/9/2011		
Cropping systems	cotton	cotton +intercrop	Inter copping system
PR Bt hybrid cotton	95	190	284
Bt hybrid cotton+ pigeon pea 8:2	76	203	279
Bt hybrid cotton+ soybean 2:2	84	171	254
Bt hybrid cotton+ field bean 2:2	88	162	250
Bt hybrid cotton+ marigold 2:2	90	185	275
Bt hybrid cotton+ maize 2:2	119	107	225
Bt hybrid cotton+ roselle 2:2	96	193	290
Bt hybrid cotton+ castor 2:2	90	82	172
CD±5%	15	20	24
F1: 90:20:37 N:P:K kg ha^{-1} 2% Urea+0.2%Mg+0.06% B	94	161	253
F2: 90:20:37 N:P:K kg ha^{-1} alongwith 5 kg Mg + 2 kg B ha^{-1}	90	161	251

Table 6. Contd.

F3: 113:24:47 N:P:K kg ha^{-1} 2% Urea+0.2%Mg+ 0.06% B twice	91	164	254
F4: 113:24:47 N:P:K kg ha^{-1} alongwith 5 kg Mg + 2 kg B ha^{-1}	95	161	255
SE±5%	8	4	6
90 x 45 cm	93	161	254
90 x 30 cm	92	102	253
SE±5%	3	4	5

drilled legumes during seedling droughts.

Conclusion

Transgenic Bt hybrid cotton +soybean intercropping can improve 89% in CEY, a profitability of US $ 662 ha^{-1} with a C:B ratio of 1: 2.99. A fertilizer dose of 90:20:37 for transgenic Bt hybrid cotton and 14:13:0 N:P:K kg ha^{-1} for soybean is sufficient with foliar correction of nutrient deficiencies by 2%Urea for N, 0.2%Mg for Mg, 0.06% B for Boron deficiency.

Conflict of Interest

The authors have not declared any conflict of interest.

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