academicJournals

Vol. 8(24), pp. 3177-3185, 27 June, 2013
DOI: 10.5897/AJAR2012.6665
ISSN 1991-637X ©2013 Academic Journals
http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Profitability and FUE of intercropping with *Bt* hybrid cotton in *vertisols* of central India

A. Ravinder Raju* and Soniya K. Thakare

Division of Crop Production, Central Institute for Cotton Research, P. O. Bag No. 2 Shankarnagar Post Office, Nagpur 440010 (M. S.) India.

Accepted 17 June, 2013

***Bt* hybrid cotton (*Gossypium hirsutum* L.) was intercropped in paired row (PR) planting at 90×135×45 cm in *Vertisols* at Central Institute for Cotton Research, Nagpur, India (21°09'N 79° 09'E, altitude 331 MSL) during 2008, 2009 and 2010 years. Paired row planted *Bt* hybrid cotton was intercropped (45/135 cm) with marigold (*Tagetes erecta* L)/soybean (*Glycine max* L.)/hybrid maize (*Zea mays* L.)/castor (*Ricinus communis* L.)/field bean (*Dolichus lablab* L.) + fennel (*Foeniculum vulgare Mill. syn. F*) compared with sole *Bt* hybrid cotton and conventional strip cropping of *Bt* hybrid cotton + pigeon pea (*Cajanus cajan* L.) in 90×45 cm in 8:2 ratio in Randomised Block Design. Sole *Bt* hybrid cotton was planted at 90 × 45 cm significantly out yielded over paired row *Bt* hybrid cotton (135 × 45 cm) only in normal to deficit rainfall years. PR planted *Bt* hybrid cotton population was insufficient to exploit the resources under adverse climatic conditions and needed more closer spacing than 45 cm. Pigeon pea strip and castor intercropping reduced the biomass, yield, nutrient uptake and recovery of applied fertilizer in *Bt* hybrid cotton, but better performed in a year of high rainfall. N, P uptake, NPK fertilizers recovery were significantly higher in sole *Bt* hybrid cotton which was similar to that of PR *Bt* hybrid cotton based intercropping systems. NUE were not significantly improved in intercropping systems in the absence of sufficient plant populations of both cotton and intercrops under adverse climatic conditions. Paired row *Bt* hybrid cotton significantly improved fertilizer uptake, recovery and benefitted from N fertilizer applied to intercropped marigold/maize. *Bt* hybrid cotton intercropped with castor/ field bean and fennel or marigold systems produced similar net returns of 880 to 940 US $ compared to 460 and 640 US $ ha^{-1} in paired row and sole *Bt* hybrid cotton respectively.**

Key words: *Bt* hybrid cotton, cotton equivalent yield, fertilizer recovery, fertilizer use efficiency, intercropping, nutrient use efficiency, small farms.

INTRODUCTION

Cotton industry employs about 47 Million people (Osakwe, 2009). Changing climate is influencing through onset, withdrawal and distribution of monsoon rain, challenged their livelihoods during 1972, 2003, 2012 droughts (Vyas, 2013). Mild seedling droughts of two weeks duration can be tolerated by cotton and found beneficial in 2007, 2011, 2012 followed by normal rains, while prolonged droughts of more than 6-8 weeks in 2012 western Maharashtra state(India) could reduce the seed cotton yields to 37 to 59% (VJAS, 2011, Asha latha et al., 2012; Vyas, 2013). Strip cropping of medium duration hybrid cotton (180 days) with long duration pigeon pea (210 days) is a farmer's practice in central and south India for protein food supplement and firewood needs (Giri et al., 2007). Risk and uncertainty imposed by changing climate could be managed by adoption of

*Corresponding author. E-mail: bumaraju@gmail.com. Tel: +9199750 55630.

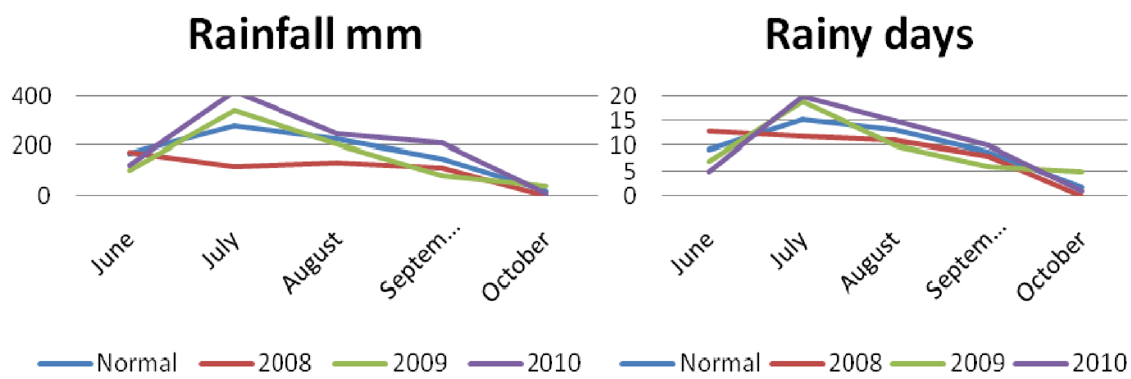

Figure 1. Rainfall distribution and rainy days at the experimental site.

location-specific diversified intercropping systems in small farms (Sankaranarayanan et al., 2010) due to better interception and infiltration of rainfall and later tapping it (Gokhale et al., 2011). Choice of intercrops can vary depending on the ecological conditions, land holding size and marketing possibilities (Brintha and Seran, 2009; Machado, 2009). Advantage of Intercropping is due to difference in use of natural resources by the component crops in labour intensive small farms (Lithourgidis et al., 2011). Paired row planting of cotton is one way of accommodating the required population of the cotton crop and creating inter space wide enough to accommodate intercrop (Nalayini et al., 2011). Fertilizer application in proportion to the crop population for better expression of land equivalent ratio (LER) is advocated due to higher nutrient demand in intercropping systems (Giri et al., 2006). Marigold (*Tagetes erecta* L.) is a multipurpose commercial flower crop grown profitably in Central India on *Vertisols* with a potential refuge for *Bt* hybrid cotton besides controlling nematodes in the soil (Figure 2). Vittal et al. (2004) recommended intercropping with cotton + pigeon pea/soybean and maize depending upon the rainfall and type of soil for improving the crop diversification, food security and profitability. Wide spread adoption of commercial soybean and *Bt* hybrid cotton improved their productivity and profitability, but it could not be sustained in recent years due to severe pest infestation on soybean and reduced seed cotton yields due to earliness of introduced Bt hybrid cotton under changing climate respectively (Anonymous, 2010b). Recommendations for intercropping were made by state agriculture universities (SAU) like suitable varieties for intercropping and strip cropping along with tolerant herbicides for weed control (Anonymous, 2010 a, c). Indian Council of Agricultural Research (ICAR) identified the main constraints in adopting commercial intercropping in small farms, were planting, weed management and harvesting difficulties. Comprehensive validation of available intercropping knowledge in newly expanding *Bt* hybrid cotton based cropping systems was funded by ICAR in its Technology Mission on Cotton (TMC) Mini Mission-I with the existing intercultural hoes and modern herbicides. Therefore, a field experiment was planned to study the performance of intercropping with *Bt* hybrid cotton, which could improve the profitability by reducing the risk through crop diversification in space and time.

MATERIALS AND METHODS

Study 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 (Figure 1) in the past 115 years. Highest recorded daily rainfall was 304 mm on 14 July 1994. Summers are extremely hot lasting from March to June, with maximum temperatures occurring in May. Winter lasts from November to January, during which temperatures can drop below 10°C. The highest recorded temperature was 48.6°C on 29 May 2012, while the lowest was 3.9°C. However, fluctuation in onset of monsoon rains with a seedling drought of 14 to 29 days was not uncommon (Figure 1). Soil analysis of experimental site observed, soil depth as 0.7 m, soil textural class clay loam, pH 8.1, organic carbon 0.45%, available $N:P_2O_5:K_2O$ 280:15:300 kg ha^{-1}. DTPA extractable Zn 0.57 ppm and Mn 2.54 ppm. Cotton area of 45 and 52% is planted on shallow and medium deep *Vertisols.* Farmers plant 80% cotton area as dry sowing with pre monsoon showers between 25 to 29th June. Strip cropping of 8 rows of non Bt hybrid cotton and 2 rows of long duration pigeon pea at same spacing (90×90 cm) was the prevalent practice over centuries, which continued with the introduction and replacement by Bt hybrid cotton since 2002. Mixed Intercropping in cotton/cereals with grain legumes was followed by primitive tribes in Central and North east India. Advent of hybrid cotton with check row planting in 1972 replaced the drilling of prevailing G. *arborem* cotton and *G. hirsutum* improved cotton varieties. Wide spread adoption of *Bt* hybrid cotton between 2002 and 2009 also replaced (98%) conventional medium to long duration cotton hybrids by medium duration *Bt* hybrid cotton. *Bt* hybrid cotton profitability reduced due to steep rise in cost of input prices and labour wages for weeding and picking (Gadgil, 2011). Present objective of the programme was to identify intercrops suitable for different rainfall fluctuations for further testing and evaluation at multi location trials for their

Table 1. Treatment details in *Bt* hybrid cotton based intercropping system.

Treatments	Herbicides applied	Fertilizers applied kg ha^{-1}		
		N	P_2O_5	K_2O
Sole *Bt* hybrid cotton NCS145'*Bunny*"	Three intercultural operations and two hand weedings	90	45	45
PR *Bt* hybrid cotton(*Bt* cotton)	PPI of Pendimethalin 1.0 kg a.i. ha^{-1}	90	45	45
Bt cotton + soybean'JS-93-05'	Pre em. Oxyflurofen 0.1 kg a.i. ha^{-1}	131	62	45
Bt cotton + pigeon pea'BSMR 763'	Pre em. Oxyflurofen 0.1 kg a.i. ha^{-1}	118	56	45
Bt cotton + marigold'African tall'	Pre em. Oxyflurofen 0.1 kg a.i. ha^{-1}	200	155	155
Bt cotton + maize'*Komal*'	Pre em. Oxyflurofen 0.1 kg a.i. ha^{-1}	156	78	73
Bt + Field bean *Pushpak*+ Fennel'Local'	PPI of Pendimethalin 1.0 kg a.i. ha^{-1}	131	80	62
Bt cotton + castor 'AKC-1'	Pre em. Oxyflurofen 0.1 kg a.i. ha^{-1}	123	67	45

suitability under the umbrella of modern herbicides with the existing farm implements.

Methodology

A field experiment was conducted with eight treatments in RBD design with four replications during 2008, 2009 and 2010 summer monsoon seasons. Treatment details were: T_1: Sole *Bt* hybrid cotton (90×45 cm) with 90:45:45, T_2:Paired row *Bt* hybrid cotton (PR 90/135 cm) with 90:45:45, T_3: T_2: + soybean(45 × 10 cm) with 131:62:45, T_4: *Bt* hybrid cotton + pigeon pea(90 × 45 cm) with 118:56:45, T_5: T_2: + marigold (45 × 22.5) with 200:155:155, T_6: T_2: + maize (45 × 22.5 cm) with 156:78:73, T_7: T_2: + shrub field bean (45 × 10 cm) and fennel (45 × 10 cm) with 131:80:62, T_8: T_2: + castor (45 × 22.5 cm) with 123:67:45 kg ha^{-1} N: P_2O_5: K_2O respectively. Details of varieties, herbicides used and fertilizers applied were given in Table 1. 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 at the recommended dose for Bt hybrid cotton regardless of sole or paired row. However, for intercropping recommended dose of intercrop fertilizer dose in proportion to the intercrop population was applied (Table 1).

Weed management

Need based plant protection measures along with three intercultural operations and two hand weedings were given to remove herbicide tolerant weeds. In the year 2008, 2010 a blanket pre plant incorporation (PPI) of Pendimethalin 1.0 kg ha^{-1} a.i. was applied, whereas in 2009 the herbicide was rotated with Oxyflurofen 0.1 kg ha^{-1} a.i. as pre emergence spray in 500 L ha^{-1} except for sensitive field bean + fennel (Pendimethalin). In order to use the existing hoes, only two rows of intercrops were accommodated in between two paired rows. Popular five tyned soybean marker (45 cm) was used for planting intercrops 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. Weed incidence was measured after 3rd interculture and hand weeding in both the years and the data was converted into $\sqrt{(x+0.5)}$ before subjecting it to statistical analysis. Soil moisture was measured by oven dry method at regular intervals. 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 November.

RESULTS AND DISCUSSION

Performance of sole Vs. paired row of *Bt* hybrid cotton

Significant differences in mean seed cotton yields 1.2 t ha^{-1} under sole cotton with higher plant 0.84 t ha^{-1} with lower than recommended plant stand of 16,296 plants ha^{-1} with paired row planting under under extreme rainfall situations (Table 2). However, ' t ' test among sole and paired row planted cotton across the years found no significant differences with a probability of 0.054 was observed with 0.87 Pearson's correlation. Seed cotton yield advantage due to higher plant density was conspicuous in a year of relatively deficit rainfall (>two weeks), was possible due to significantly higher production of biomass, recovery of applied fertilizer nutrients and N and P uptake (Tables 3 and 4) resulting in higher boll number and seed cotton yield. No advantage was noticed in a year of higher rainfall due to major leaching losses. Results were in agreement with VJAS, 2011; Asha latha et al. (2012) and Vyas, 2013 observations of yield losses to the extent of 37 to 50% under abnormal weather conditions, where recovery of *Bt* hybrid cotton growth and yield was limited by its shorter duration. Returns from sole cotton with higher plant density (Table 6) were 30% significantly higher than paired row *Bt* hybrid cotton as sole cropping confirmed by paired t test. Therefore, a lower plant density at 16, 296 plants ha^{-1} is not economical for *Bt* hybrid cotton which is determinate in nature can not compensate for yield reduction under adverse climatic conditions. Unless it is grown with a profitable inter/ relay crop, no agronomic advantage was noticed with paired row planting of *Bt* hybrid cotton.

Similar results were observed by Hebbar et al. *(*2007) in *Bt* hybrid cotton with Cry 1 Ac gene, which retained higher number of early formed bolls, due to competition

Table 2. Seasonwise cotton and intercrops yield .stand of at 24,691 plants ha^{-1} as compared to only Intercrop 1=between paired row single intercrops and intercrop 2 = component of intercrop mixture.

Treatments	Intercrop yield (tha^{-1})		Seed cotton yields (t ha^{-1})				Cotton equivalent yield (t ha^{-1})			
	1	2	2008	2009	2010	Mean	2008	2009	2010	Mean
Sole *Bt* hybrid cotton			2.3	0.7	0.6	1.2	2.3	0.7	0.6	1.2
PR *Bt* cotton *(Bt* cotton)			1.2	0.8	0.6	0.8	1.2	0.8	0.6	0.8
Bt cotton + soybean	0.4		1.8	0.9	0.6	1.1	2.0	1.1	0.9	1.3
Bt cotton + pigeon pea	0.4		1.0	0.9	0.6	0.8	1.2	1.3	1.5	1.3
Bt cotton + marigold	1.2		2.1	0.6	0.6	1.1	2.8	1.0	1.8	1.8
Bt cotton + maize	4.6		1.9	1.0	0.5	1.1	1.9	1.2	1.1	1.4
Bt + field bean + fennel	1.5	0.04	1.8	0.8	0.6	1.1	2.0	1.2	1.8	1.7
Bt cotton + castor	0.4		1.1	0.8	0.5	0.8	1.2	1.0	2.3	1.5
Seasons CD (P=0.05)			1.6	0.8	0.6	0.14	1.8	1.0	1.3	0.2
Intercrops. CD (P=0.05)						0.21				0.3
Intercrop x Season CD(*P*=0.05)						0.72				0.8

Table 3. Biomass and nutrient uptake of *Bt* hybrid cotton and intercrops.

Treatments	Biomass (t ha^{-1})			Nutrient uptake (kgha^{-1})					
				Cotton			Intercrop		
	Cotton	Intercrop	Total	N	P	K	N	P	K
Sole *Bt* hybrid cotton	2.7		2.7	66	17	21			
PR *Bt* hybrid cotton*(Bt* cotton)	1.7		1.7	46	11	38			
Bt cotton + soybean	2.3	3.7	6.0	58	17	24	91	23	61
Bt cotton + pigeon pea	1.9	0.7	2.6	45	11	33	15	5	10
Bt cotton + marigold	2.3	1.9	4.2	53	14	25	38	16	28
Bt cotton + maize	2.5	5.9	8.4	61	14	33	114	45	100
Bt cotton + Field bean and fennel	2.1	2.4	4.5	51	13	37	46	17	35
Bt cotton + castor	1.8	1.3	3.2	44	13	28	34	13	21
SEm±						6			
Intercrops CD(*P*=0.05)	0.3	0.9	0.8	7	3		19	10	20
2008	2.4	2.6	4.3	57	17	31	57	13	37
2009	2.1	2.7	4.1	50	14	32	59	30	55
2010	2.0	2.7	4.0	52	12	26	53	17	36
SEm±				3.3			4		
Seasons CD(*P*=0.05)	0.3				2	4		6	8
Intercrop x Season SE m±		0.2	0.2	17			17		
CD(*P*=0.05)	0.7	1.0	1.1		12	20		25	37

for nutrients to the developing bolls the vegetative growth is restricted and become more compact and determinate. Concept of paired row planting of cotton was evolved in 1800s for bushy medium to longer duration cottons for better crop management was not found to be useful for Insect/ herbicide resistant cottons (Stephenson and Lancastor, 2007). Similarly, in *Bt* hybrid cottons also as confirmed by private companies, despite best efforts made in the initial introduction of *Bt* hybrid cotton with wide row spacing and high input management (Mandava and Alapati, 2007).

Nutrient requirement, fertilizer recovery and input use efficiency

Nutrient requirement of *Bt* hybrid cotton based intercropping systems depends on *Bt* cotton/ intercrop duration, weed competition, soil depth, prevailing weather conditions and crop management. Fertilizer recovery by sole *Bt* hybrid cotton was 45% N, 54% Phosphorous, 58% more potash than paired row planting of *Bt* hybrid cotton at same fertilizer application level in *Vertisols* of assured rainfall area (AESR 10.2) due to the farmer

Table 4. Recovery of applied fertilizers by *Bt* hybrid cotton and intercrops.

Treatments	*Bt* hybrid cotton			Intercrop		
	N	P	K	N	P	K
Sole *Bt* hybrid cotton	0.7	0.4	0.8			
PR *Bt* hybrid cotton*(Bt* cotton)	0.5	0.3	0.5			
Bt cotton + soybean	0.6	0.4	0.7	1.2	0.8	
Bt cotton + pigeon pea	0.5	0.3	0.6	0.3	0.2	
Bt cotton + marigold	0.6	0.3	0.7	0.2	0.1	0.1
Bt cotton + maize	0.7	0.3	0.8	0.9	0.9	1.7
Bt cotton + *Field bean* and fennel	0.6	0.3	0.6	0.6	0.3	1.2
Bt cotton + castor	0.5	0.3	0.6	0.6	0.3	
CD(*P*=0.05)	0.1	0.1	0.1	0.2	0.2	0.5
2008	0.6	0.4	0.7	0.6	0.3	0.8
2009	0.6	0.3	0.7	0.7	0.6	1.3
2010	0.6	0.3	0.6	0.6	0.4	0.9
SEm±	0.0			0.2		
CD(*P*=0.05)		0.1	0.1		0.1	0.3
SEm±	0.2					0.5
CD(*P*=0.05)		0.3	0.5	0.4	0.5	

Table 5. Fertilizer and Nutrient use efficiency *Bt* hybrid cotton and intercrops.

Treatments	Bt hybrid cotton						Intercrops						Bt hybrid cotton Intercropping system			
	FUE			NUE			FUE			NUE			Phosphorous NUE			
	N	P	K	N	P	K	N	P	K	N	P	K	2008	2009	2010	Mean
Sole *Bt* hybrid cotton	13	27	27	17	73	31	13	27	27	18	82	34	39	92	113	82
PR *Bt* cotton	9	19	19	18	87	37	9	19	19	18	91	37	60	74	138	91
Bt cotton + soybean	12	24	24	19	62	32	8	18	30	9	35	15	34	33	37	35
Bt cotton + pigeon pea	9	19	19	19	74	33	9	20	29	23	88	39	90	71	104	88
Bt cotton + marigold	12	24	24	20	75	33	6	7	7	18	58	28	76	48	49	58
Bt cotton + maize	12	25	25	18	78	31	7	15	14	8	27	11	35	16	30	27
Bt + *Field bean*+fennel	12	24	24	20	78	36	10	16	23	17	62	27	80	39	65	62
Bt cotton + castor	9	18	18	18	63	27	10	18	34	19	60	31	53	59	67	60
SEm±		3	3	2	12	4	3	6								
CD(*P*=0.05)	4								15	8	39	16				
2008	15	29	29	23	82	41	9	18	23	16	58	27				
2009	12	25	25	22	82	33	9	18	23	17	54	23				
2010	6	13	13	11	57	23	9	17	22	17	76	34				
SEm±	2						0.4	1	1	1						
CD(*P*=0.05)		6	6	3	21	6					14	5				
SEm±	2	16	16	2		16	3	4	7	6		12				
CD(*P*=0.05)					55						75					

realized cotton price was US $. 0.60, 0.90 and 1.20 / kg seed cotton in 2008, 2009 and 2010 respectively higher plant density. N P fertilizer use efficiency (FUE) was significantly superior due to better fertilizer recovery of applied N P fertilizer nutrients as confirmed by paired " t '' test. However, N P fertilizer nutrient use efficiency 'NUE' and K FUE/ NUE were statistically similar among paired and sole cotton with higher plant density due to similar genetic ability of the plant roots under minimal competition (Table 5).

NPK fertilizer recovery by *Bt* cotton did not reduced significantly by long duration intercrops pigeon pea

Table 6. Investments and returns 0000 US \$ ha^{-1} from *Bt* hybrid cotton based cropping systems.

Treatments	Cost of cultivation			Returns			Returns from cotton				Returns from intercrop			
	cotton	Inter	Total	Gross	Net	C: B rato	2008	2009	2010	Mean	2008	2009	2010	Mean
Sole *Bt* hybrid cotton	0.28		0.26	0.92	0.64	0.051	1.36	0.66	0.7	0.92				
PR *Bt* cotton	0.26		0.24	0.7	0.46	0.041	0.7	0.7	0.7	0.7				
Bt cotton + soybean	0.26	0.06	0.32	1.1	0.68	0.049	1.08	0.78	0.94	0.94	0.14	0.2	0.14	0.16
Bt cotton + pigeon pea	0.26	0.04	0.28	1.24	0.7	0.057	0.62	0.78	1.46	0.96	0.08	0.4	0.36	0.28
Bt cotton + marigold	0.26	0.12	0.38	1.56	0.88	0.055	1.24	0.5	1.68	1.14	0.44	0.38	0.44	0.42
Bt cotton + maize	0.26	0.06	0.32	1.18	0.76	0.050	1.14	0.86	1.08	1.02	0.02	0.2	0.22	0.16
Bt + *Field bean*+fennel	0.26	0.1	0.36	1.5	0.94	0.058	1.1	0.7	1.76	1.18	0.12	0.38	0.44	0.32
Bt cotton + castor	0.24	0.04	0.28	1.46	0.9	0.056	0.68	0.7	2.04	1.14	0.08	0.18	0.74	0.34
CD(P=0.05)	0.02	0.02	0.02	0.26	0.22	0.008				0.22				0.1
YearsSEm±														
CD(P=0.05)	0.008		0.02	0.14	0.12	0.005				0.12				0.04
Interaction CD(P=0.05)	0.04	0.08	0.06	0.72	0.64	0.024				0.66				0.22

and castor, despite of marginal superiority shown by castor due to higher plant stand in intercropping as confirmed by " t '' test (Table 5). Lowest biomass was recorded in year of highest rainfall with lowest *Bt* hybrid cotton yields in 2010. Nitrogen phosphorous and potash fertilizer / nutrient use efficiency of intercropped cotton was non significantly differed by intercropping with castor or strip cropped with pigeon pea. Similarly nitrogen and phosphorous fertilizer use efficiency of intercropped castor was significantly superior over pigeon pea probably due to higher plant stand as intercrop compared to pigeon pea as strip cropping in replacement series with *Bt* hybrid cotton with only 20% population. Nitrogen phosphorous and potash fertilizer and nitrogen nutrient use efficiency for long duration castor intercropping and pigeon pea strip cropping with *Bt* hybrid cotton system were statistically similar, except PK nutrient use efficiency of deep rooted, long duration pigeon pea was significantly superior to that of intercropped castor with *Bt* hybrid cotton system (Table 5) as confirmed respective t tests.

PR *Bt* hybrid cotton could improve the P and K uptake by improving the recovery of applied fertilizer when intercropped with marigold for fresh flower market, significantly higher than PR Bt hybrid cotton alone. Nitrogen fertilizer recovery, NPK F/NUEs was statistically similar to that of PR *Bt* hybrid cotton alone and PR *Bt* hybrid cotton intercropped with marigold. However, NPK NUE was non significantly differed due to leaching losses and also favoured more weed growth in PR *Bt* hybrid cotton when intercropped with marigold indicates reconsideration of presently used recommended fertilizer dose of N:P_2O_5: K_2O at 200 kg ha^{-1} for sole marigold by state agriculture university ANGRAU, Hyderabad, India (Table 1) than a moderate dose recommended by TNAU, Coimbatore, India of 90:75:75 kg ha^{-1} N:P_2O_5: K_2O (TNAU, 2013) is sufficient under rainfed production at 2 t ha^{-1} fresh flowers These results also indicate the need of specific nutrient doses for intercropping system, rather than general NPK doses for individual crops proportion to respective populations (Giri et al., 2006) may exceeds the intercropping requirement.

Fertilizer recovery in *Bt* hybrid cotton when it was intercropped with maize was 35% higher N, but reduced 22% P and 35%K fertilizer recovery than PR *Bt* hybrid cotton alone which was similar to sole *Bt* hybrid cotton (Table 5). This clearly indicates the fertilizer dose of 156:78:73 kg ha^{-1} N: P_2O_5:K_2O for PR *Bt* hybrid cotton + maize intercopping benefited *Bt* hybrid cotton from nitrogen fertilization where as intercropped maize, competed for PK fertilizers with cotton which is inefficient in using PK fertilizers. NPK F/NUE of *Bt* hybrid cotton in intercropping system was comparable to sole/ PR *Bt* hybrid cotton alone.

However, NPK F/NUE of *Bt* hybrid cotton + maize intercropping system as such was significantly inferior to PR/ sole *Bt* hybrid cotton system except P FUE which was comparable to PR, due to high fertilizer/ nutrient demanding

Table 7. Weed incidence m^2 as influenced by different *Bt hybrid* cotton based cropping systems.

Treatments	24th August , 2008				September, 2009			
	135 cm intercropping		90 cm intercropping		135 cm intercropping		90 cm intercropping	
	Broad leave	Grasses	Broad leave	Grasses	Broad leave	Grasses	Broad leave	Grasses
Sole *Bt* hybrid cotton	5.7(2.5)	12.3(3.6)	6.3(2.5)	18.7(4.3)	0(1.3)	0(1.4)	0(1.6)	0(1.1)
PR *Bt* hybrid cotton	6.0(2.5)	26.7(5.0)	4.3(2.2)	13.3(3.5)	0(3.2)	0(3.3)	0.5(3.8)	0(3.8)
Bt cotton + soybean	10.3(2.9)	14.7(3.6)	2.7(1.6)	30.3(5.0)	6.0(2.2)	7.0(2.0)	8.8(2.7)	7.5(2.6)
Bt cotton + pigeon pea	1.7(1.4)	15.3(3.9)	9.0(2.5)	21.3(4.1)	7.0(2.8)	7.8(2.6)	10.0(3.3)	10.3(3.2)
Bt cotton + marigold	2.7(1.6)	44.7(6.6)	3.0(1.7)	42.3(6.5)	16.0(2.4)	20.5(2.7)	23.0(2.8)	23.8(2.8)
Bt cotton + maize	3.3(1.8)	13.0(3.4)	2.3(1.5)	18.7(4.1)	7.0(1.5)	6.0(1.4)	12.0(1.8)	9.3(1.7)
Bt + *Field bean* + fennel	6.0(2.5)	15.7(4.0)	4.7(2.1)	18.7(4.3)	9.0(2.9)	8.0(2.6)	14.0(3.5)	13.8(3.4)
Bt cotton + castor	10.3(3.1)	27.0(5.0)	4.0(2.1)	23.7(4.9)	8.0(3.1)	5.0(3.4)	9.5(3.7)	9.5(3.7)
SEm$\pm$	(0.8)	(1.1)	(0.8)	(1.3)	8.0(2.4)	6.7(2.4)	11.0(2.9)	10.7(2.8)

$\sqrt{(x+0.5)}$ conversions in parenthesis.

maize intercrop, whose biomass production was high compared to the green cobs it produced as component crop. There is a need to closely re examine the nutrient need for this system in future.

NPK fertilizer recovery in PR *Bt* hybrid cotton when intercropped with soybean was significantly superior to PR *Bt* hybrid cotton alone or statistically similar to that of sole *Bt* hybrid cotton as confirmed by paired 't'' tests. However, NPK F/ NUE of PR *Bt* hybrid cotton as component of PR intercropped with soybean was statistically no different with PR/ sole *Bt* hybrid cotton. K FUE of *Bt* hybrid cotton intercropped with soybean was 38% significantly higher than PR *Bt* hybrid cotton alone, where as NPK NUE of the system was significantly inferior to both PR/ sole *Bt* hybrid cotton due to luxurious consumption of nutrients as less grain was produced due to biotic (semilooper damage) and abiotic stresses (drought/excess rains) on soybean.

NPK fertilizer recovery in PR *Bt* hybrid cotton when intercropped with + field bean + fennel was statistically similar to PR *Bt* hybrid cotton alone but NK recovery was significantly 30% lower than sole *Bt* hybrid cotton. NPK F/NUE of both as *Bt* hybrid cotton component in intercropping as well as intercropping system was found to be non significantly differed due to wide variations among the seasons as confirmed by paired t tests.

Adoptability of intercropping systems

PR *Bt* hybrid cotton intercropped with tall and longer duration castor (Table 6), PR *Bt* hybrid cotton + marigold or PR *Bt* hybrid cotton intercropped with field bean + fennel were significantly superior in net returns, than sole Bt hybrid cotton. Visible premium price to early birds in niche market is also subjected to crop management/market risks under varied climatic conditions. *PR Bt* hybrid cotton + soybean and *PR* Bt hybrid cotton + pigeon pea strip cropping systems were more amenable with better crop management knowledge and minimal marketing risks in the absence of price advantage were at par with sole *Bt* hybrid cotton. Intercropped field bean produced 1.47 t/ha of green pods and 40 kg/ha fennel, where as intercropped marigold also produced 1.2 t /ha of fresh flowers both are in demand in semi urban market with similar net returns. The price advantage in 2009 and 2010 for *Bt* hybrid cotton did not brought changes in C:B ratio and therefore, intercropping did not covered the risk (Table 7).

Weed management cost and control efficiency

Although marigold, soybean, castor showed numerically more weeds in 2008 and only marigold in 2009 but non significantly influenced by the cropping systems and herbicides rotation. Weed management cost in marigold was significantly highest by 54% in intercropped rows and 42% in cotton rows compared to cotton + pigeon pea strip cropping system (Table 8). This was probably due to excess N available in the

Table 8. Weed management cost US $ ha in different intercropping systems under herbicides rotation.

Treatments	28, August, 2008		September, 2009	
	Broad row	Narrow row	Broad row	Narrow row
Sole *Bt* hybrid cotton	8.9		4.2	
PR *Bt* hybrid cotton	9.9		3.0	
PR *Bt* hybrid cotton + soybean	12.8	15.2	9.1	11.0
PR *Bt* hybrid cotton + pigeon pea	11.4	8.9	13.7	12.9
PR *Bt* hybrid cotton + marigold	16.3	13.7	20.0	18.8
PR *Bt* hybrid cotton + maize	8.4	4.1	14.1	14.6
PR *Bt* hybrid cotton + Field bean and fennel	8.9	7.0	12.4	12.3
PR *Bt* hybrid cotton + castor	15.3	9.6	9.9	9.7
Mean of Oxyflurofen	11.8	7.4	10.6	9.6
Mean of intercrops	12.0	8.7	14.0	13.7
SEm$\pm$	3.1	5.1		
CD(P=0.05)			6.3	4.6

system, besides weaker stems of marigold resulted inefficient hoeing /weed control.

Conclusion

PR *Bt* hybrid cotton population was insufficient need to be planted more closely to accommodated recommended plant population. Profitability of intercropping was observed only with inbuilt risk of crop management and marketing under varied climatic conditions with castor/ marigold/ Field bean intercropping. Maize intercropping may be suitable in the absence of pigs. It can be concluded that *Bt* hybrid cotton based intercropping systems requires Nitrogen nutrient proportion to the population of intercrop than PK.

ACKNOWLEDGEMENT

This research project received financial assistance from Indian Council of Agricultural Research, Ministry of Agriculture, government of India under technology mission on cotton Mini Mission I is duely acknowledged.

ABBREVIATIONS

ANGRAU, Acharya N. G. Ranga Agriculture University, Hyderabad (India); **JAU,** Junagad Agriculture University, Junagad, Gujarat (India); **LER,** land equivalent ratio; **RAU,** Raichur Agriculture University, Raichur, Karnataka (India); **SAUs,** State Agriculture Universities; **TNAU,** Tamil Nadu Agriculture University, Coimbattore, India; **VJAS,** Vidarbha Jana Andolan Samiti. Nagpur (India).

REFERENCES

Anonymous (2010a). Recommendations of university of agricultural sciences, University of Agriculture Sciences, Raichur.htm.

Anonymous (2010b). COTTON FIBRE__www.texmin.nic.in/ .../ Fibre_Policy_Sub_ %20 Groups_ Report_ dir_mg_d_20100608_1.pdf.

Anonymous (2010c). Recommendations/Technology developed during last 11 years. Junagadh Agricultural University (1999-2010). P. 3. www.jau.in/ attachments proceedings Reco-Last-11-Years.pdf.

Asha latha KV, Munisamy G, Bhat ARS (2012). Impact of climate change on rainfed agriculture in India: a case study of Dharwad. Int. J. Environ. Sci. Dev. 3(4):368-371. www.ijesd.org/show-38-489-1.html.

Brintha I, Seran TH (2009). Effect of paired row planting of radish (*raphanussativus*l.) intercropped with vegetable *Amaranthus* on yield components of radish in sandy *regosol*. J. Agric. Sci. 4(1):19-28.

Gadgil M (2011). Cotton farmers seek higher support prices. Wed, Nov 09 2011. 11 56 PM IST. http:// www.livemint.com/ Politics/ XIXag8qj6oWr9g1Or9HaQP/ Cotton-farmers-seek-higher-support-prices.html.

Giri AN, Deshmukh MN, Gore SB (2006). Nutrient management in cotton *(Gossypium hirsutum)* - based cropping systems. Indian J. Agron. 51(1):34-36.

Giri AN, Gore SB, Kapse PS (2007). Performance of cotton and pigeon pea under different row Proportions. J. Cotton Res. Dev. 21(1):58-60.

Gokhale DN, Shinde VS, Gadade GD, Sawargaonkar GL, Zade KK (2011). Sustaining rainfed *Bt* cotton productivity through moisture conservation and integrated nutrient management technique. J. Cotton Res. Dev. 25(2):197-201.

Hebbar KB, Rao MRK, BM Khadi (2007). Synchronized boll development of *Bt* cotton hybrids and their physiological consequences. Curr. Sci. 93:693-695. www.ias.ac.in/currsci/sep102007/695.pdf.

Lithourgidis AS, Dordas CA, Damalas CA, Vlachostergios DN (2011). Annual intercrops: an alternative pathway for sustainable agriculture. Rev. Article Aust. J. Crop Sci. 5(4):396-410.

Machado S (2009). Does intercropping have a role in modern agriculture. J. Soil Water Conserv. 64(2):54-57. A.doi:10.2489/ jswc.64.2.55A .http://cbarc.aes.oregonstate.edu/ sites/default /files/ JSWC64 _2_55 machado_ proof _3. pdf.

Mandava RP, Alapati S (2007). *Bt* cotton offers planting at higher planting densities in India, September 12, WCRC-4 Lubbock Texas.

Nalayini P, Paul Raj S, Sankaranarayanan K (2011). Growth and yield performance of cotton (*Gossypium hirsutum*) expressing *Bacillus thuringiensis var. Kurstaki* as influenced by polyethylene mulching and planting techniques. Indian J. Agric. Sci. 81(1):55-59.

Osakwe E (2009). Cotton fact sheet, India, ICAC reporter, May 19. www.icac.org/econ_stats/country_facts/e_india.pdf.

Sankaranarayanan K, Nalayini P, Sabesh M, Rajendran K, Nachane RP, Sankaranarayanan K, Praharaj C S, Nalayini P, Bandyopadhyay

K, Gopalakrishnan N (2010). Climate change and its impact on cotton (*Gossypium sp.).* Indian. J. Agric. Sci. 80(7):561-575.
Stephenson DO, Lancaster SW (2007). Planting Pattern (a.k.a. Row Spacing) Early 1800's, cotton seeded on beds with 4-foot 15-Inch vs.
Single 38-inch cotton paired southeast and mid-south perspective ncc. confex. com / ncc/ 2008/ recordingredirect.cgi/id/1712.
TNAU (2013). Fertilizer schedule for flower crops. www.agritech.tnau.ac.in/ horticulture/ ERTILIZER%20SCHEDULE%20FOR%20FLOWER%20CROPS.pdf.
Vittal KPR, Rajendran TP Ravindra Chary G, Maruthi Sankar GR, Srijaya T, Ramakrishna YS, Samra JS, Gurbachan S (2004). Districtwise stability in *Bt* cotton production Technical Bulletin No.2/2011 Edited by All India coordinated research project for dryland agriculture Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad 500:059.
VJAS (2011). Excess rain and recent flood damaged standing Bt
Vyas S (2013). Centre releases Rs 778 crore drought aid to Maharashtra. Times of India, Mumbai. TNN Jan 10, 2013, 08.53 PM IST. http://articles.timesofindia.indiatimes.com/2013-01-10/mumbai/36257327_ 1_centre-releases-rs-crore-drought-aid-relief-and-mitigation-measures.
xa.yimg.com/.../Excess+rain+and+recent+flood+damaged+standing+.