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Studies on heterosis for yield and fibre quality traits in GMS hybrids of upland cotton (*Gossypium hirsutum* L.)

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ABSTRACT: Forty four cotton (*Gossypium hirsutum* L.) hybrids were produced from a line x tester crossing programme with 15 parents (four lines and eleven testers). The primary objective of this study was to determine the useful heterosis in *Gossypium hirsutum* for seed cotton yield, its component traits and fibre quality parameters in 44 GMS (genetic male sterility) based cross combinations. The analysis of variance indicated that the mean squares of genotypes were significant for seed cotton yield (kg/ha), monopodia, sympodia and bolls/plant, boll weight (g), GOT (%), micronaire value and strength (g/tex) except 2.5 per cent span length (mm) indicated the presence of variability among hybrids and their parents. Studies revealed that none of the cross combinations exhibited significant heterosis over the check hybrid CSHH 198 for seed cotton yield, number of bolls per plant, boll weight and sympods/plant and micronaire value. Significant heterosis monopods/plant, seed index, ginning percentage, 2.5 per cent span length and fibre strength were detected over the conventional check hybrid CSHH 198. For number of monopods in GMS 17 x CISV-1 (81.1%), seed index in GMS 20 x *Bikaneri narma* (15.9%), ginning percentage in GMS 17x 007 DA (10.4%) showed the highest and significant positive heterosis over the conventional check hybrid CSHH 198. For quality traits, 2.5 per cent span length in GMS 26 x 006 DA (7.4%) and for fibre strength GMS 21 x 006 DA (13.4%) showed the highest and significant positive heterosis over the conventional check hybrid CSHH 198. The cross combination involving female parent GMS 21 and male parent 006 DA. *Bikaneri narma* recorded the significant positive heterosis for most of the characters so could be exploited in producing hybrid cotton.

Key words: Cotton, genetic male sterility, *Gossypium hirsutum,* standard heterosis

Cotton is of a great economic importance as it plays a vital role in agricultural and industrial development, and earning of foreign exchange through export of its raw materials as well as finished products. To increase seed cotton yield, exploiting heterosis is one of the best method. Heterosis in cotton has been observed by various workers (Arshad *et al.,* 2001; Babar *et al.,* 2001). Heterotic studies can also provide the basis for exploitation of valuable hybrid combinations and their commercial utilization in future breeding programmes. In the present study GMS based hybrids produced from line x tester mating design were evaluated to find out the useful heterotic combinations for seed cotton yield, its component traits and fibre quality parameters.

MATERIALS AND METHODS

The material used in the present study was developed by line x tester crossing programme involving fifteen upland cotton genotypes. Among them four lines GMS 17, GMS 20, GMS 21 and GMS 26 used as females and eleven testers PA (M), M 45, S 123, LH 900, PIL 8, CISV 1, Ratna, 007 DA, 006 DA, H 10 (M), *Bikaneri narma* used as males were crossed at the Central Institute for Cotton Research, Regional Station, Sirsa during 2009-2010. Each line was crossed with all the eleven testers individually in a line x tester design to develop forty four hybrids. The crosses along with check CSHH 198 were grown in two row plot in a randomized block design (RBD) with three replications during the year 2010-2011. Between row to row and plant to plant row spacing were 100 x 45 cm, respectively. Five competitive plants were selected randomly to record the data on bolls/plant, boll weight, monopods, sympods, seed index and ginning percentage. At maturity, open bolls were hand harvested and were ginned in a laboratory for estimation of ginning percentage and analyzed for fibre quality parameters *viz*., 2.5 per cent span length (mm), micronaire value, and bundle strength (g/tex) on High Volume Instrument (HVI) as per the standard methods. The data were used for statistical analysis for estimation of heterosis. According to this method economic heterosis was calculated as mean of F_1 performance over the mean performance of the check hybrid (CSHH 198) and was expressed in percentage.

RESULTS AND DISCUSSION

The analysis of variance indicated that the mean squares due to genotypes for all the characters were significantly different, indicating the presence of variability in the experimental material. The mean squares due to parents and hybrids were significant for seed cotton yield (kg/ ha), monopodia, sympodia and bolls/plant, boll weight (g), GOT (%), micronaire value and strength (g/tex) except 2.5 per cent span length. Similarly the interactions due to parents *v/s.* hybrids were also significant for seed cotton yield, monopods, bolls/plant, ginning outturn, micronaire value and bundle strength except sympods/plant, boll weight and 2.5 per cent span length. This indicated that hybrids and parents showed significant genetic variation.

A comparison of the mean values of the parents and hybrids in respect of different characters is presented in Table 1. The range of mean values among the parents for seed cotton yield varied from 478 (007 DA) to 1636 kg/ha (GMS 20) and for cross combinations it ranged from 957 (GMS 17 x 007 DA)) to 2269 kg/ha (GMS 26 x LH 900 and GMS 26 x Ratna). For bolls/plant, mean values of the parents was observed lowest in 007 DA (15.6 bolls/plant) and highest in GMS 20 (37.1 bolls/plant) and for hybrids it was found to be lowest in GMS 20 x PIL 8 (24.2 bolls/plant) and highest in GMS 20 x S 123 (45.1 bolls/plant). The mean values for average boll weight ranged from 2.67(LH 900) to 3.83 g (007 DA) in parents and 2.71g (GMS17 x PA (M)) to 4.10 g (GMS 21 x 007 DA) in hybrids. The range of mean values among the parents for number of monopods per plant was from 0.9 (007 DA) to 4.6 (CISV-1) and among crosses it ranged from 1.3(GMS 17 x 007 DA) to 5.4 (GMS 17 x CISV 1). The sympods/plant varied from 6.2 (H 10M)) to 11.1 (Ratna) in parents and 7.4 (GMS 17 x *Bikaneri narma*) to 11.2 (GMS 26 x Ratna) in cross combinations. The range of mean values among the parents for seed index varied from 5.5 (006 DA) to 8.1 (Ratna) and for cross combinations it ranged from 4.7 (GMS 26 x PA (M)) to 8.7 (GMS 20 x *Bikaneri narma*). For ginning percentage, the range of mean values among the parents was observed lowest in PIL 8 (30.7 %) and highest in M 45(35.5 %) and for hybrids it varied from 32.0 per cent in two crosses GMS 20 x PIL 8 and GMS 21 x 006 DA to 37.0 per cent in GMS 17 x 007 DA. The mean value for 2.5 per cent span length ranged from 25.6 mm (*Bikaneri narma*) to 29.4 mm (006 DA) and 26.7 (GMS 26 x 006 DA) to 30.6 mm (GMS 26 x 006 DA) in parents and hybrids, respectively. The mean values among the parents varied from 3.9 (*Bikaneri narma*) to 5.3 (CISV 1) and for cross combination varied from 4.2 (GMS 20 x Ratna, GMS 21 x Ratna and GMS 26 x *Bikaneri narma*) to 5.2 (GMS 17 x PIL-8, GMS 20 x PIL 8 and GMS 26 x M 45) for fibre fineness. In parents, the lowest mean value was observed by *Bikaneri narma* (19.2g/tex) and highest by PA (M) (23.5g/tex) likewise for cross combinations, the lowest mean value was observed by the cross GMS 26 x S 123 and GMS 26 x *Bikaneri narma* (20.3g/tex) and highest was by GMS 21 x 006 DA (25.4 g/tex) for bundle strength (g/tex).

Heterosis estimates over zonal check CSHH 198 for different characters is presented in Table 2. It showed that for seed cotton yield, the cross combination GMS 26 x Ratna hybrid recorded the highest seed cotton yield of 2269 kg/ ha and however, none of the combinations exhibited significant positive heterotic values over the zonal check CSHH 198. It was found that GMS based cross combinations could not cross the performance of the check hybrid CSHH 198. These results are in accordance with the previous study of Tuteja *et al.,* (2011b). Similarly, for boll, none of the hybrids exhibited significant positive heterosis. All the cross combinations showed negative heterotic effects for boll as the parents involved in the present study do not have variability for this trait.

For boll weight, only two crosses GMS 21 x 007 DA and GMS 26 x PIL 8 showed positive heterosis values and remaining crosses were showed negative heterosis effects but none of cross combinations showed any significant heterosis values. Similar results have been reported by Tuteja *et al.,* (2011a).

The heterosis for monopods/plant was found in positive direction for 24 hybrids. Maximum heterotic effects were observed in cross combinations GMS 17 x CISV 1 (81.1%) and GMS 21 x *Bikaneri narma* (74.4%). None of the cross combinations exhibited significant positive heterosis for sympods/plant. Similar findings

Table 1. Mean and range values of hybrids and parents for seed cotton yield and its component traits

Parents	Seed cotton yield (kg/ha)	Bolls/ plant	Boll weight (g)	Mono-podia/ plant	Sym-podia/ plant	Seed index	GOT (%)	2.5 per cent span length (mm)	Micro-naire value	Bundle strength (g/tex)
PA (M)	1148	36.0	3.09	3.1	9.4	6.67	35.2	29.3	5.1	23.5
M 45	1235	31.2	3.40	2.4	9.1	7.13	35.5	26.8	5.0	20.0
S 123	1389	33.3	2.94	2.8	10.0	7.97	33.8	27.1	5.1	20.1
LH 900	1481	36.8	2.67	3.7	10.1	6.00	33.2	27.2	5.2	21.2
PIL 8	1451	33.3	3.21	1.6	10.2	6.33	30.7	28.3	5.0	22.0
CISV 1	787	27.0	3.47	4.6	6.9	5.93	33.5	27.7	5.3	21.4
Ratna	1512	34.8	3.07	2.4	11.1	8.10	34.0	28.2	4.7	22.1
007 DA	478	15.6	3.83	0.9	6.3	6.17	35.3	26.6	4.8	20.7
006 DA	611	20.1	2.73	2.2	6.6	5.57	33.3	29.4	4.6	21.6
H 10 (M)	556	21.9	2.80	2.6	6.2	6.07	34.2	26.8	5.3	20.0
Bikaneri narma	1559	29.6	3.07	3.9	9.0	6.40	33.3	25.6	3.9	19.2
GMS 17	1296	28.8	3.00	2.6	8.0	6.30	34.2	28.0	5.0	22.0
GMS 20	1636	37.1	3.45	3.7	9.3	7.07	34.2	27.0	5.0	20.8
GMS 21	1420	24.0	3.34	2.7	8.8	7.43	33.2	27.6	5.0	20.4
GMS 26	1179	30.3	3.15	3.8	8.2	6.67	34.0	27.2	4.7	20.5
Range	**478-1636**	**15.6-37.1**	**2.67-3.83**	**0.9-4.6**	**6.2-11.1**	**5.5-8.1**	**30.7-35.5**	**25.6-29.4**	**3.9-5.3**	**19.2-23.5**
Hybrids/Cross										
GMS 17 x PA (M)	1914	36.1	2.71	4.6	9.7	5.03	35.2	30.3	4.8	24.4
GMS 17 x M 45	1944	39.6	3.75	3.7	10.1	7.13	34.5	27.9	4.7	21.5
GMS 17 x S 123	2130	31.8	3.43	3.6	8.4	6.33	36.5	27.5	5.1	20.4
GMS 17 x LH 900	1682	33.8	2.75	3.8	8.3	6.00	32.7	27.6	5.0	21.4
GMS 17 x PIL 8	1312	29.7	3.57	3.7	7.8	5.90	32.8	28.4	5.2	22.2
GMS 17 x CISV 1	1636	38.9	3.44	5.4	9.6	6.83	33.5	28.3	4.9	22.2
GMS 17 x Ratna	1821	34.3	3.26	2.2	10.1	5.83	36.2	28.4	4.8	21.3
GMS 17 x 007 DA	957	29.0	3.20	1.3	8.6	5.20	37.0	27.5	5.0	21.1
GMS 17 x 006 DA	1821	39.2	2.90	3.2	10.2	7.03	35.0	27.9	4.8	21.3
GMS 17 x H 10 (M)	1111	34.1	3.41	2.4	8.9	6.00	32.8	27.9	5.0	21.3
GMS 17 x *Bikaneri narma*	1497	38.3	3.16	4.3	7.4	6.17	36.3	26.8	4.4	20.4
GMS 20 x PA (M)	1003	36.8	3.43	3.7	9.1	6.17	35.0	28.9	4.5	23.4
GMS 20 x M 45	2114	37.4	3.81	3.3	10.2	7.17	35.0	27.9	5.0	21.2
GMS 20 x S 123	1929	45.1	3.52	4.8	9.9	6.03	34.2	27.4	4.7	21.7
GMS 20 x LH 900	1728	34.1	3.46	4.4	9.3	6.87	35.0	27.6	4.7	21.2
GMS 20 x PIL 8	1250	24.2	3.87	1.4	8.4	7.43	32.0	28.2	5.2	22.0
GMS 20 x CISV 1	1404	35.6	3.34	4.7	9.2	6.23	35.8	28.5	4.8	22.6
GMS 20 x Ratna	1466	32.3	3.42	3.2	9.9	7.00	35.3	27.9	4.2	21.8
GMS 20 x 007 DA	1127	31.6	3.63	1.8	9.8	7.10	34.7	28.9	4.5	24.6

Contd...

Table 1. contd...

GMS 20 x 006 DA	1142	31.0	3.25	2.8	8.4	6.20	34.5	26.7	4.8	20.6
GMS 20 x H 10 (M)	1080	33.2	3.55	4.0	9.9	8.33	33.5	29.5	5.1	24.9
GMS 20 x *Bikaneri narma*	2114	32.3	3.53	3.6	9.4	8.73	36.2	27.9	5.0	21.5
GMS 21 x PA (M)	1543	35.9	3.12	3.1	9.2	8.53	33.3	29.7	4.7	25.0
GMS 21 x M 45	1898	40.8	3.82	4.9	8.6	6.83	32.7	27.8	5.0	21.8
GMS 21 x S 123	1574	32.3	3.43	4.7	8.4	6.43	34.8	30.4	4.6	23.2
GMS 21 x LH 900	2068	38.1	3.36	3.9	9.6	6.83	33.2	27.6	5.1	21.0
GMS 21 x PIL 8	1528	34.8	3.80	4.7	10.0	6.27	32.5	30.0	5.0	24.6
GMS 21 x CISV 1	1543	27.2	3.37	3.0	8.8	8.50	32.3	28.5	5.0	23.2
GMS 21 x Ratna	2238	33.8	3.77	4.1	9.3	6.93	33.7	29.1	4.2	23.1
GMS 21 x 007 DA	1775	34.2	4.10	4.0	9.2	8.50	33.7	29.6	4.7	24.8
GMS 21 x 006 DA	1173	31.7	3.75	2.7	8.9	8.70	32.0	30.0	4.7	25.4
GMS 21 x H 10 (M)	1420	29.9	3.51	3.4	7.8	6.53	33.3	27.3	4.7	21.7
GMS 21 x *Bikaneri narma*	2099	36.7	3.75	5.2	8.2	6.37	33.5	27.2	4.7	21.2
GMS 26 x PA (M)	1960	37.3	3.19	3.9	10.0	4.77	34.2	27.5	4.8	21.4
GMS 26 x M 45	1929	29.9	3.17	1.9	9.4	5.70	34.5	28.6	5.2	22.3
GMS 26 x S 123	1867	33.1	3.41	3.9	9.0	6.67	34.3	27.2	4.9	20.3
GMS 26 x LH 900	2269	33.6	3.12	3.4	9.7	5.30	33.7	27.2	5.0	21.0
GMS 26 x PIL 8	2037	35.2	4.04	2.9	9.3	7.73	32.7	28.6	4.8	23.0
GMS 26 x CISV 1	2114	35.6	3.33	4.9	9.1	6.73	32.7	30.0	4.8	24.0
GMS 26 x Ratna	2269	41.3	3.12	2.4	11.2	6.83	35.0	28.1	4.7	20.5
GMS 26 x 007 DA	1991	36.4	3.47	3.3	9.9	5.83	35.8	29.1	5.0	22.1
GMS 26 x 006 DA	1250	37.1	3.30	3.6	9.7	6.43	35.2	30.6	4.7	24.4
GMS 26 x H 10 (M)	1790	35.0	3.01	2.6	9.1	6.20	33.0	28.8	4.7	21.8
GMS 26 x *Bikaneri narma*	1944	39.6	2.98	4.6	9.3	5.50	34.7	26.7	4.2	20.3
Range	**957-2269**	**24.2-45.1**	**2.71-4.10**	**1.3-5.4**	**7.4-11.2**	**4.7-8.7**	**32.0-37.0**	**26.7-30.6**	**4.2-5.2**	**20.3-25.4**

Table 2. Estimates of economic heterosis of GMS based crosses for yield and its component traits

Hybrids/Cross	Seed cotton yield (kg/ha)	Bolls/ plant	Boll weight (g)	Mono-podia/ plant	Sym-podia/ plant	Seed index	GOT (%)	2.5 per cent span length (mm)	Micro-naire value	Bundle strength (g/tex)
GMS 17 x PA (M)	-6.8	-30.2	-30.1	52.2*	-41.4	-33.2	5.0*	6.3*	-7.7	8.9*
GMS 17 x M 45	-5.3	-23.4	-3.3	22.2*	-38.8	-5.3	3.0	-2.1	-9.6	-4.0
GMS 17 x S 123	3.8	-38.5	-11.8	18.9*	-49.0	-15.9	9.0*	-3.5	-1.9	-8.9
GMS 17 x LH 900	-18.0	-34.6	-29.3	25.6*	-49.4	-20.4	-2.5	-3.2	-3.8	-4.5
GMS 17 x PIL 8	-36.1	-42.6	-8.0	22.2*	-52.9	-21.7	-2.0	-0.4	0.0	-0.9
GMS 17 x CISV 1	-20.3	-24.7	-11.5	81.1*	-42.0	-9.3	0.0	-0.7	-5.8	-0.9
GMS 17 x Ratna	-11.3	-33.5	-16.1	-25.6	-38.8	-22.6	8.0*	-0.7	-7.7	-4.9
GMS 17 x 007 DA	-53.4	-43.9	-17.5	-55.6	-48.1	-31.0	10.4*	-3.5	-3.8	-5.8
GMS 17 x 006 DA	-11.3	-24.1	-25.2	7.8	-38.0	-6.6	4.5*	-2.1	-7.7	-4.9
GMS 17 x H 10 (M)	-45.9	-34.0	-12.3	-18.9	-46.1	-20.4	-2.0	-2.1	-3.8	-4.9
GMS 17 x *Bikaneri narma*	-27.1	-25.8	-18.5	44.4*	-54.9	-18.1	8.5*	-6.0	-15.4	-8.9
GMS 20 x PA (M)	-51.1	-28.8	-11.6	22.2*	-44.8	-18.1	4.5*	1.4	-13.5	4.5*
GMS 20 x M 45	3.0	-27.5	-2.0	11.1	-38.0	-4.9	4.5*	-2.1	-3.8	-5.4
GMS 20 x S 123	-6.0	-12.7	-9.3	58.5*	-39.9	-19.9	2.0	-3.9	-9.6	-3.1
GMS 20 x LH 900	-15.8	-34.0	-11.0	47.8*	-43.4	-8.8	4.5*	-3.2	-9.6	-5.4
GMS 20 x PIL 8	-39.1	-53.1	-0.3	-52.2	-49.0	-1.3	-4.5	-1.1	0.0	-1.8
GMS 20 x CISV 1	-31.6	-31.2	-14.1	55.6*	-44.1	-17.3	7.0*	0.0	-7.7	0.9
GMS 20 x Ratna	-28.6	-37.4	-11.8	7.8	-39.9	-7.1	5.5*	-2.1	-19.2	-2.7
GMS 20 x 007 DA	-45.1	-38.9	-6.4	-41.1	-40.8	-5.8	3.5*	1.4	-13.5	9.8*
GMS 20 x 006 DA	-44.4	-40.0	-16.3	-7.8	-48.8	-17.7	3.0	-6.3	-7.7	-8.0
GMS 20 x H 10 (M)	-47.4	-35.7	-8.5	33.3*	-39.9	10.6*	0.0	3.5	-1.9	11.2*
GMS 20 x *Bikaneri narma*	3.0	-37.4	-9.2	18.5*	-42.8	15.9*	8.0*	-2.1	-3.8	-4.0
GMS 21 x PA (M)	-24.8	-30.5	-19.7	3.3	-44.0	13.3*	-0.5	4.2	-9.6	11.6*
GMS 21 x M 45	-7.5	-21.1	-1.7	63.3*	-48.1	-9.3	-2.5	-2.5	-3.8	-2.7
GMS 21 x S 123	-23.3	-37.4	-11.7	55.6*	-49.0	-14.6	4.0*	6.7*	-11.5	3.6
GMS 21 x LH 900	0.8	-26.2	-13.5	29.6*	-42.1	-9.3	-1.0	-3.2	-1.9	-6.3
GMS 21 x PIL 8	-25.6	-32.7	-2.2	55.6*	-39.3	-16.8	-3.0	5.3	-3.8	9.8*
GMS 21 x CISV 1	-24.8	-47.3	-13.3	0.0	-46.8	12.8*	-3.5	0.0	-3.8	3.6
GMS 21 x Ratna	9.0	-34.6	-2.8	37.0*	-43.4	-8.0	0.5	2.1	-19.2	3.1
GMS 21 x 007 DA	-13.5	-33.7	5.6	33.3*	-44.0	12.8*	0.5	3.9	-9.6	10.7*
GMS 21 x 006 DA	-42.9	-38.7	-3.3	-11.5	-46.1	15.5*	-4.5	5.3	-9.6	13.4*
GMS 21 x H 10 (M)	-30.8	-42.1	-9.7	14.4	-52.9	-13.3	-0.5	-4.2	-9.6	-3.1
GMS 21 x *Bikaneri narma*	2.3	-29.0	-3.5	74.4*	-50.0	-15.5	0.0	-4.6	-9.6	-5.4
GMS 26 x PA (M)	-4.5	-27.8	-17.9	30.0*	-39.4	-36.7	2.0	-3.5	-7.7	-4.5
GMS 26 x M 45	-6.0	-42.1	-18.5	-36.7	-42.8	-24.3	3.0	0.4	0.0	-0.4
GMS 26 x S 123	-9.0	-35.9	-12.1	30.0*	-45.5	-11.5	2.5	-4.6	-5.8	-9.4
GMS 26 x LH 900	10.5	-35.0	-19.7	14.4	-41.4	-29.6	0.5	-4.6	-3.8	-6.3
GMS 26 x PIL 8	-0.8	-31.8	3.9	-3.3	-43.4	2.7	-2.5	0.4	-7.7	2.7
GMS 26 x CISV 1	3.0	-31.2	-14.2	63.3	-44.8	-10.6	-2.5	5.3	-7.7	7.1*
GMS 26 x Ratna	10.5	-20.0	-19.7	-18.5	-31.9	-9.3	4.5*	-1.4	-9.6	-8.5
GMS 26 x 007 DA	-3.0	-29.5	-10.7	11.1	-40.1	-22.6	7.0*	2.1	-3.8	-1.3
GMS 26 x 006 DA	-39.1	-28.2	-14.9	18.5*	-41.4	-14.6	5.0*	7.4*	-9.6	8.9*
GMS 26 x H 10 (M)	-12.8	-32.3	-22.5	-14.8	-44.8	-17.7	-1.5	1.1	-9.6	-2.7
GMS 26 x *Bikaneri narma*	-5.3	-23.4	-23.2	52.2*	-43.5	-27.0	3.5*	-6.3	-19.2	-9.4

* Significant at p= 0.05

were also observed by Tuteja *et al.* (2011b) and Tuteja *et al.*, (2013). Among 44 crosses, only 6 cross combinations had significant positive heterosis values for seed index and maximum heterosis cross GMS 20 x *Bikaneri narma* showed (15.9%) followed by GMS 21 x 006 DA (15.5%). Pole *et al.,* (2008) also reported heterosis for seed index.

Eighteen cross combinations displayed positive and significant heterosis for ginning percentage but the cross combinations GMS 17x 007 DA showed maximum heterotic effects by a magnitude of 10.4 per cent. In cotton 2.5 per cent span length is a new criteria for measurement of fibre length. In the present study, only three cross combinations showed significant and positive heterosis and maximum heterosis in the cross GMS 26 x 006 DA (7.4%).The results are in conformity with Rajamani *et al.,* (2009) and Patil *et al.*, (2011) . Micronaire value is an important fibre quality trait in judging lint quality of cotton. All the cross combinations showed negative heterosis effect for micronaire value.The decrease in micronaire value is an indication of fibre fineness. The results are in the agreement with earlier research findings of Rauf *et al.*, (2005) and Rajamani *et al.,* (2009). Significant and positive heterotic effects for fibre strength were observed in ten of the forty four cross combinations but GMS 21 x PA (M) and GMS 21 x 006 DA exhibited maximum heterosis of 11.6 per cent and 13.4 per cent, respectively.

The scope of heterosis breeding is for exploitation of heterosis. The cross combination involving female parent GMS 21 and male parents 006 DA, *Bikaneri narma* recorded significant positive heterosis for most of the characters. Thus, the female parent GMS 21, male parents 006 DA, *Bikaneri narma* can be used further for development of GMS based hybrids in cotton.

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Performance of conventional *v/s* male sterility based hybrids for yield and quality traits in *Gossypium hirsutum* L.

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Abstract: *Gossypium hirsutum* is the most commonly grown species among the four cultivated species. Noticeable heterosis has been reported in cotton. Hybrid seed in cotton is generally produced by conventional method. The cost of hybrid seed produced by the conventional method is high. Performance of cotton hybrids produced by different breeding methods *i.e.* conventional *v/s* male sterility based systems were compared for seed cotton yield, ginning outturn (%), 2.5 per cent span length (mm), fibre strength (g/tex) and micronaire value (µg/in) for three years. Overall mean performance of 191 cytoplasmic genetic male sterility based hybrids; 123 genetic male sterility based hybrids and 155 conventional hybrids revealed that conventional hybrids produced the maximum seed cotton yield (2225 kg/ha) followed by genetic male sterility based hybrids (2157 kg/ha). The cytoplasmic genetic male sterility hybrids performed poorly with mean seed cotton yield of 1406 kg/ha. The ginning outturn, 2.5 per cent span length, fibre strength and micronaire values of all the hybrids produced by different methods were almost similar.

Key words : Conventional hybrids, male sterility, seed cotton yield

Cotton is an important fibre crop of India. A noticeable heterosis for seed cotton yield has been reported by (Khadi *et al.,* 1993, Wang and Li 2002). The major reason of not widely utilizing heterosis in cotton is the high cost of hybrid seed production as it involved high amount of skilled manpower in hand emasculation and pollination (Raut,1998). There are four approaches of hybrid seed production *i.e.* the removal of male reproductive organ by hand emasculation or introducing male sterility by different means *i.e.* chemical hybridizing agents or genetic male sterility (GMS) or cytoplasmic genetic male sterility (CGMS). The chemical hybridizing agents' method is not feasible in cotton due to long flowering period. Most of hybrid seed production in major cotton growing countries like India and China is done by hand emasculation and pollination mainly because of non availability of potential male sterile lines. The setting per cent of crossed bolls is also low and it varies from 20 to 40 per cent depending upon location, genotype, wind direction, speed and skill of labour and climatic conditions. Thus, the development of hybrid based on male sterility system is the necessity to reduce the cost of hybrid seed.

Higher seed cotton yield is the prime target in any breeding programme and level of heterosis should be maintained in the process of hybrid seed production by different methods. Hence concerted efforts were made to compare the seed cotton yield of hybrids developed by different methods *i.e.* conventional, cytoplasmic genetic male sterility and genetic male sterility.

MATERIALS AND METHODS

The experiment was conducted continuously for three years *i.e.* 2002-2003 to 2004-2005 to compare the performance of cotton hybrids produced by conventional system, cytoplasmic genetic male sterility system and genetic male sterility system. A gene pool of promising genotypes was developed to be used as male parents. Superior genotypes for different traits were identified and converted into cytoplasmic male sterile lines (A line) and genetic male sterile lines (GMS).

Majority of CMS (A) lines had sterile cytoplasm from *G. harknessii* species and fertile counterparts were used as maintainer lines (B); the potential restorer lines were identified for restorability of fertility of CMS A lines to produce the fertile hybrid. Superior parents for yield were selected on phenotypic basis to attempt conventional, GMS based and CGMS based crosses. During 2002-2003 to 2004-2005 forty one diverse CMS (A) lines namely RS 875, RS 2013, SH 175, H 1117, HS 182, H 1180, Super okra, RS 810, CAK 053, CAK 8835 (*aridum*), CAK

3456 (*aridum*), CAK 1234, Supriya, Suman, Laxmi (C), Akola 442, LRA 5166, LRK 516, PKV Rajat, LCMS 3, LCMS 509, LCMS 2, LCMS 5, RCMSA 2, RCMSA 3, DMSA 20, J 205, CIR 59, GSCMS 24, GSCMS 31, L 89, L 603, LCM 501, LCMS 511, RCMS 5, RCMS 6, HCMS 11, CAK 2160, CAK 8801, CAK 8 and NH 258 were used in the development of hybrids. The restorers used as male parents for restoration of fertility of CMS (A) lines were Athens, AKH 073, AKH 07, DHY 286-1, GSR 6, GSR 22, AKH 98-81, AKH 98-8, AKH 39, GSRH 24, DR 4, DR 104, DR 2, AKH 0816, AKH 186, LR 103, GSRH 41, GSRH 26, CIR 6, DR 8 and DR 7, HGMS 1, HGMS 2, HGMS 3, HGMS 4, HGMS 5, HGMS 6, HGMS 7, HGMS 17, H. Super Okra, H 1117, H 999, H 974, MCU 5, Gregg 1 and Gregg 2. The number of hybrids developed by cytoplasmic genetic male sterility, genetic male sterility and conventional methods were 68, 21 and 68 in the year 2002-2003; 15, 33 and 41 in the year 2003-2004 and 108, 69 and 46 in the year 2004-2005 respectively and same were tested in different trials.

In conventional hybrid seed production emasculation was done in the evening h preferably between 3 to 5 PM and pollination was done on the next morning between 8.30 AM to 12.30 noon. In case genetic male sterility (GMS) system two types of flowers *i.e.* fertile heterozygote and sterile flower were appeared at the time of flowering *i.e.* first fortnight of July. The fertile heterozygote were rogued out and sterile flower plants were used as female parent and crossed with the male parent to produce hybrid seed, whereas in cytoplasmic genetic male sterility (CGMS) system, the female line (CMS A) is crossed with fertility restorer line (male parent) which again restores its fertility. The seed cotton produced on female parents was the hybrid seed.

The material was grown in randomized block design with three replications and recommended cultural practices were followed. Seed cotton yield was recorded in kg/plot and converted into kg/ha in each year and mean yield of different hybrids attempted by different breeding methods was recorded and finally overall mean of 3 years was obtained. Similar observations were also recorded for fibre traits *viz.* ginning per cent, 2.5 per cent span length (mm), fibre strength (g/ tex) and micronaire value (ug/in) in the year 2002-2003 in GMS ored hybrids, whereas in 2003-2004 and 2004-2005 these observations were recorded in conventional and genetic male sterility based hybrids.

RESULTS AND DISCUSSION

The mean performance of hybrids developed by cytoplasm genetic male sterility system was compared with hybrids developed by genetic male sterility and conventional system (Table 1). The mean seed cotton yield of conventional hybrids (68) was (2208 kg/ha) during 2002-2003 and it ranged from 958 to 2921 (kg/ha). The GMS hybrids produced the mean seed cotton yield 2167 kg/ha with a range of 1042 to 2809 (kg/ha), whereas the CMS based hybrid performed poorly with mean seed cotton yield of 1446 (kg/ha) that ranged from 444 to 2553 (kg/ ha). The studies conducted during the year 2003-04 revealed the superiority of conventional hybrids (2148 kg/ha) over the CGMS (1905 kg/ ha) and GMS (1819 kg/ha) based hybrids for seed cotton yield. Studies conducted during 2004-2005 showed the superiority of GMS based hybrid (2450 kg/ha) for seed cotton yield over the conventional hybrids (2324 kg/ha) as well as CGMS based hybrids (1332 kg/ha).

Overall mean performance of 191 CGMS based, 123 GMS based and 155 conventional hybrids evaluated in different years showed that conventional hybrid produced the highest seed cotton yield (2225 kg/ha) followed by GMS based hybrids (2157 kg/ha). Cytoplasmic genetic male sterility based hybrids consistently showed poor performance for seed cotton yield in different years (1406 kg/ha). The probable reason may be the sterile cytoplasm from *G. harknessii* transferred in female parent may be associated with genes for low yield. Reduction in seed cotton yield in CCMS based hybrids was also reported by (Yagya Dutt *et al.,* 2004, Lather *et al.,* 2001). Weaver (1986) and Zhu *et al.,* (1998) observed detrimental effects of sterile cytoplasm on yield and its contributing traits in *hirsutum* cotton. The probable reason for low yield in such hybrids might be due to lower viability of pollen grains resulting low boll setting as compared to hybrids with normal cytoplasm.

The comparison of genetic male sterility based hybrids with conventional hybrids indicated

Table 1. Mean seed cotton yield (kg/ha) and range of hybrids tested in different years

Year	Parameter	Conventional hybrids	GMS based hybrids	CMS based hybrids
2002-2003	**Mean**	**2208 (68)**	**2167 (21)**	**1446 (68)**
	Range	958 - 2921	1042 -2809	444 -2553
	Conventional check	2496	2467	2331
2003-2004	**Mean**	**2148 (41)**	**1819 (33)**	**1905 (15)**
	Range	370 -3601	183 - 2932	926 -2732
	Conventional check	2145	2291	2469
2004-2005	**Mean**	**2324 (46)**	**2450 (69)**	**1333 (108)**
	Range	206 -3740	247 -3395	164 -3018
	Conventional check	2481	2630	3072
2002-2005	**Mean**	**2225 (155)**	**2157 (123)**	**1406 (191)**
	Range	206 -3740	183 -3395	164 -3018
	Conventional check	2374	2463	2624

Values in parenthesis is number of hybrids evaluated

that the seed cotton yield of both the classes of hybrids were almost similar. This indicated the possibilities of exploitation of GMS based hybrids at commercial scale without any risk of restoration and detrimental effect of CMS A can also be avoided.

GMS system results significant reduction in cost of hybrid seed production than that of conventional method because of elimination of process of emasculation otherwise that requires high labour cost. Moreover in male sterility system there is no damage to the floral parts

Table 2. Mean and range of ginning outturn of hybrids tested in different years

Year	Parameter	Conventional hybrids	GMS based hybrids	CMS based hybrids
2002-2003	**Mean**	**33.0**	**34.0**	**33.0**
	Range	28.4 -36.0	28.0 -38.0	28.0 -38.0
	Conventional check	36.6	32.0	31.0
2003-2004	**Mean**	**32.5**	**33.0**	**34.0**
	Range	30.2 -34.7	29.0 -38.0	30.0 -39.0
	Conventional check	32.8	33.0	33.0
2004-2005	**Mean**	**33.5**	**34.0**	**35.0**
	Range	24.8 - 40.7	30 - 37	31- 40
	Conventional check	36.6	33.0	35.0
2002-2005	**Mean**	**33.3**	**34.0**	**34.0**
	Range	24.8 - 40.7	28.8 - 38.0	28.0 - 40.0
	Conventional check	35.3	33.0	33.0

Table 3. Mean and range of 2.5 per cent span length of hybrids tested in different years

Year	Parameter	Conventional hybrids	GMS based hybrids	CMS based hybrids
2002-2003	**Mean**	**29.7**	**27.6**	**27.8**
	Range	19.3 - 30.4	22.0 - 33.0	25.3 - 30.0
	Conventional check	26.0	26.8	27.4
2003-2004	**Mean**	**28.0**	**27.6**	
	Range	22.0 - 32.4	22.5 - 30.0	
	Conventional check	26.9	26.3	
2004-2005	**Mean**	**27.0**	**29.1**	
	Range	24.5 - 28.5	22.7- 33.1	
	Conventional check	25.9	27.1	
2002-2005	**Mean**	**27.5**	**27.9**	
	Range	19.0 - 32.4	22.0 - 33.1	
	Conventional check	26.3	26.7	

Table 4. Mean and range of fibre strength (g/ tex) of hybrids tested in different years

Year	Parameter	Conventional hybrids	GMS based hybrids	CMS based hybrids
2002-2003	**Mean**	**22.3**	**22.5**	**21.9**
	Range	17.8 - 24.8	19.3 - 23.6	19.7- 23.9
	Conventional check	22.0	21.8	23.2
2003-2004	**Mean**	**22.5**	**22.8**	
	Range	19.2 - 27.6	18.0- 26.5	
	Conventional check	23.4	22.3	
2004-2005	**Mean**	**22.0**	**23.7**	
	Range	20.2 - 23.4	19.7 - 27.8	
	Conventional check	20.8	22.8	
2002-2005	**Mean**	**22.4**	**22.8**	
	Range	17.8 - 29.8	18.0 - 27.8	
	Conventional check	22.1	22.3	

Table 5. Mean and range of micronaire value of hybrids tested in different years

Year	Parameter	Conventional hybrids	GMS based hybrids	CMS based hybrids
2002-2003	**Mean**	**4.8**	**4.4**	**4.4**
	Range	3.4 - 5.8	3.0 - 5.2	3.4 - 5.1
	Conventional check	4.2	4.6	4.4
2003-2004	**Mean**	**5.0**	**5.0**	
	Range	4.0 - 6.5	4.0 - 5.6	
	Conventional check	5.1	4.8	
2004-2005	**Mean**	**5.0**	**4.6**	
	Range	4.2 - 5.1	4.1- 5.1	
	Conventional check	4.9	4.8	
2002-2005	**Mean**	**4.9**	**4.7**	
	Range	3.4 - 6.5	3.0 - 5.6	
	Conventional check	4.7	4.7	

ultimately resulting in more setting of crossed bolls with less labour cost. Possibilities of development of CMS A x R hybrids can't be ruled out as yield produced by a CMS A x R hybrid was as high as 3018 kg/ha against 3072 kg/ha of conventional check hybrid in the year 2004-2005. Further it was also observed that potential yield level attained by a hybrid can not be realized in successive years indicated more role of environmental condition on this character.

There is need for diversification of CMS A x R system to counter the negative effect of *G. harknessii* by using of sterile cytoplasm from other sources like *G. aridum* or *G. anomalum* and other alternative is to develop cotton hybrids based on genetic male sterility. Number of such hybrids were superior for seed cotton yield to conventional check hybrid indicated the possibilities for the development of hybrid with reduced hybrid seed production cost.

Observations on ginning outturn (%) of hybrids developed by cytoplasm genetic male sterility, genetic male sterility and conventional methods were compared (Table 2). There was not much variation in mean values of hybrids tested 2002-2003 to 2004-2005 for ginning outturn of the hybrids developed by different methods. Present investigation confirms the findings of Shroff *et al.,* (1988) regarding ginning out turn and fibre quality of CMS A x R hybrids. There was no significant differences in mean values of 2.5 per cent span length, fibre strength and micronaire values of hybrids developed by different methods (Tables 3-5).Bhale (1999) reported contradictory results that *G. harknessii* CMS source by and large is not very ideal because this cytoplasm suppresses the yield, ginning out turn, fibre fineness.

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Studies to enhance cotton plant stand under north zone

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ABSTRACT : Experiments were carried out at Central Institute for Cotton Research, Regional Station, Sirsa during 2006 to 2009 to find out the contribution of transplanting of raised seedling, seed lot with superior seed index and pre sowing seed treatments to enhance the plant stand in field under adverse conditions during seedling stage in northern cotton growing zone of India. The transplanting of advance raised seedlings greatly contributed towards enhanced plant stand up to 97.0 per cent with yield 31.7 q/ha than normal sown crop with plant stand of 85 per cent and yield 25.1q/ha. Because of higher yield with transplanted crop the net income Rs. 6108/ha over normal sown crop was observed. The superior seed index also contributed significantly in improving plant stand and up to 89.8 per cent plant stand and yield more than 33.0 q/ha in *G. hirsutum* and plant stand 87.2 per cent with 32.6q/ha yield in *G. arboreum* was observed with use of graded seed lot having seed with superior seed index as compared to ungraded seed lot with plant stand 70.6 per cent and yield of 28.2 q/ha in *G. hirsutum* and plant stand 75.9 per cent with yield 28.2 q in *G.arboreum* species. Treated seed with KNO_3 100 mM + Imidacloprid + Vitavax showed the higher plant stand upto 87.6 per cent in *G.hirsutum* and 82.2 per cent in *G.arboreum* followed by DAP 1 per cent + Imidacloprid + Vitavax (85.7% and 79.4%) against the control (82.5%).

Keywords: Cotton seedling enhancement, transplanting, seed index, seed treatment

Cotton is the most important commercial crop which contributes nearly 65 per cent raw material for textile industry. After the introduction of *Bt* cotton, the production increased from 179 lakh bales in 2003 to 315 lakh bales during 2007-2008 but after that it started declining and was 290 lakh bales in 2008 and 295 in 2009. The productivity also declined from 560 kg/ha in 2007 to 526 kg.ha in 2008 and 496 kg/ha in 2009. The northern cotton growing zone of the country is an important zone in which cotton was grown in 15 lakh ha area and contributed 39 lakh bales during 2009-2010 which is about 13 per cent of total production of country. In this zone almost entire cotton area is covered under *Bt* hybrids except about 10 per cent under *G.arboreum* and *G.hirsutum* varieties and hybrids. The poor plant stand due to soil/ water salinity/alkalinity, crust formation due to rains just after sowing and mortality of seedlings under high temperature condition during sowing season is a serious problem and cause heavy loss in yield. The higher seed rate also cannot be advised to farmers as the cost of *Bt* seed is much higher than open pollinated varieties. Ensuring optimum plant stand under prevailing condition is a biggest challenge to the cotton researchers. The literature indicated that the improved physiological properties such as superior seed index and pre sowing seed treatments act as catalyst to improve survival rate under such adverse field situations (Lather *et al.*,1992; Meena and Deshmukh., 1990). The current study was carried out with the aim to evaluate the contribution of seed physiological properties and also of seedling transplanting for enhancing the plant stand under north zone.

MATERIALS AND METHODS

The field experiments were carried out at Central Institute for Cotton Research Regional Station, Sirsa during 2006 to 2009. The contribution of transplanting of raised seedling, seed index and pre sowing seed treatments was assessed to achieve optimum plant stand in field condition. To assess the contribution of transplanted crop, seedlings of *Bt* hybrids RCH 134 were raised in disposable cups of different height *i.e.* 4.5, 6.5 and 8.5cm with same diameter in the substratum made by mixing the coir pit, FYM and soil in the ratio of 50 : 35 : 15. In addition to that the seedling raised using saw dust, FYM and soil with 20 days seedlings was also compared as saw dust is easily available material for the farmers. The evaluation was made against two controls, first was the normal sowing on the date of raising of 20 days old seedlings in cups and second was the normal sowing on date of transplanting of the raised seedlings. Single seed in each container was used for raising the seedlings where as two seeds per dibble were used for direct sowing in both the controls. The seedlings were raised under tree shade and moisture in the containers was maintained by watering regularly. The seedlings raised in each size of container were transplanted in the field at 15, 20 and 25 days seedling age along with both the control in 4 replications at 67.5 x 60 cm spacing in randomized bloc design. In case of substratum with saw dust only 20 days seedlings raised in medium size container were transplanted for comparison. Light irrigation in transplanted crop was applied immediately after transplanting for their establishment and second irrigation after 15 days of transplanting, whereas the direct sown crop was given irrigation after 40 days of sowing. To study the role of different levels of seed index in both the hybrids, ungraded seed lot with seed index 8.2g was manually separated into three lots of seed index 9, 8.5 and 7.5g in hybrid CSHH 198 and ungraded seed lot with seed index of 4.8g into seed lot with seed index of 5.5, 5.0 and 4.5g of hybrid CICR 2. The crop using each seed lot of both the species was sown in 4 replication with randomized block design at 67.5 x 60 cm spacing. The contribution of pre sowing seed treatments with KNO3 100mM, KCl 2 per cent, DAP 1.0 per cent, *Trichoderma* and water each with imidacloprid and vitavax was assessed in field conditions. *Trichoderma* seed treatment was used without imidacloprid and water. The data on plant stand, monopodia, sympodis, plant height, boll/plant, boll weight, yield/ha, seed index, lint index and GOT were recorded in each treatment.

RESULTS AND DISCUSSION

Under the adverse conditions of high temperature during seedling stage in this zone, the seed ling burning is a serious problem and the transplanting of advance raised seed lings greatly contributed towards enhancing the plant stand in field. In all the transplanting treatments, significantly higher plant stand (upto 97%) was than both the controls *i.e.* direct sown crop on the date of seedling raising (87%) as well as on date of transplanting (85%). Among 15, 20 and 25 days seedlings, the higher plant stand was observed with 20 days seedling raised in each size of container but observed maximum (97 %) when grown in containers of size 6.5 and 8.5 cm. Although properly graded *Bt* seed was used for raising the seedling as well as normal sowing even then in this treatment 14 per cent increase in plant stand against normal sowing control was observed. In addition to substratum of coir pit, FYM and soil, the performance in saw dust, FYM and soil also compared as saw dust is easily available. In saw dust, FYM and soil also, significantly higher plant stand (94%) than normal sown crop of both the controls (87%) was observed (Table 1). Because of 20 days advance sowing with transplanting as well as early normal sowing control, the crop showed greater height (108 cm), earlier maturity, more monopodial and sympodial branches than the control. In these treatments the flowering was also early and hence the flowering period was more as compared to control. The difference for bolls/plant were non significant in transplanted as well as control but was significantly higher than the control. The differences for boll weight, seed index, lint index and ginning outturn were non significant. In all the treatments of transplanting, the yield was significantly higher than the direct sown (both the controls) which may be mainly because of better plant stand in transplanted crop. The significant and maximum yield of 31.7 q/ha and 30.7 q/ha was observed with 20 days old seed lings raised in 6.5 and 8.5 cm container than both the normal sown controls *i. e.* 27 q/ha and 25.1q/ha, respectively (Table 1). In this treatment 26 per cent increase in yield over control, sown on date of transplanting was observed. In transplanted crop raised with saw dust as the yield (29.9 q/ha) was significantly higher than the control. The boll/plant and yield in control directly sown on date of raising the seedlings was slightly higher than the control sown after 20 days at the time of transplanting of seedlings.

In transplanting system the farmers were able to get higher yield with advancing the sowing of crop which generally gets delayed due to late availability of irrigation water and late harvest of previous crop. In transplanting the farmers have to invest extra Rs. 8500 for substratum and disposable containers, Rs. 4725 for labour charges of filling the cups and transplanting of raised seedling, and Rs. 450 for three extra irrigations.

Table 1. Role of seedling transplanting in improvement of plant stand and yield in hybrid RCH 134

Treatments	Plant stand (%)	Monopodia/ plant	Sympodia/ plant	Plant height (cm)	Bolls/ plant	Boll weight (g)	Yield (q/ha)	Seed index (g)	Lint index	GOT (%)
• Small container + 15 days raised seedling	94	4.4	11.2	104	43.1	3.4	28.6	8.9	5.1	36.1
• Small container + 20 days raised seedling	93	4.8	11.8	105	43.4	3.4	28.8	8.9	5	36.2
• Small container + 25 days raised seedling	89	4.7	12.7	105	43.7	3.4	28.6	8.9	5	36.2
• Medium container + 15 days raised seedling	95	4.6	11.2	106	45.9	3.5	30.3	8.9	5.15	36.3
• Medium container + 20 days raised seedling	**97**	4.6	11.4	107	47.5	3.5	**31.7**	9.1	5.25	36.3
• Medium container + 25 days raised seedling	89	4.9	12.3	105	45.1	3.4	28.7	8.9	5.1	36.2
• Large container + 15 days raised seedling	**96**	4.6	12.2	108	46.8	3.5	**30.3**	9.0	5.2	36.5
• Large container + 20 days raised seedling	**97**	4.8	12.8	109	47.4	3.5	**30.7**	9.1	5.3	36.8
• Large container + 25 days raised seedling	94	4.8	12.2	107	47.3	3.4	28.6	8.8	4.95	35.9
• Twenty days seedling with saw dust, FYM and soil	94	4.8	11.3	105	44.1	3.5	29.9	9.0	5.1	36.1
• Control 1 (normal sowing on date of raising seedlings)	87	4.7	12.7	105	47.8	3.5	27.0	8.9	5.0	35.8
• Control 2 (normal sowing on date of transplanting)	85	4.0	10.3	97	40.6	3.4	25.1	9.1	5.0	35.6
C. D. (p=0.05)	5.1	NS	NS	6.6	3.7	NS	3.18	NS	NS	NS

Table 2. Economics of transplanted cotton versus direct sown cotton

Sr. No.	Particulars with expenditure detail	Expenditure cost: Direct sown cotton	(Rs/ha)	Transplanted cotton	(Rs/ha)
A.	**Expenditure**				
1	Pre sowing field preparation	1 deep plough @ Rs 750/ha + 2 cultivator before irrigation and 2 cultivator + one planking after irrigation for sowing @ Rs 375/ha	2650	1 deep plough @ Rs 750/ha + 2 cultivator + one planking before irrigation @ Rs 450 /ha	2100
2	Seed cost	5 packets (450 g each) @ Rs 750 each	3750	2.5 packet (450 g) @ Rs 750 each	1875
3	Direct sowing/ transplanting cost	13 labour @ Rs 135	1755	10 labour for seedling raiging + 25 labour for transplanting @ Rs 135/ labour	4725
4	Cost of container and substratum	_	_	25,000 container @ Rs 25/ 100 (Rs 6250) and 5.625 q cocopit @ Rs 400/ q (Rs 2250)	8500
5	After sowing/ transplanting irrigation charges till 40 days	_	_	3 irrigations @ Rs 150 each	450
6	Irrigation charges after 40 days	4 irrigations @ Rs 150	600	4 irrigations @ Rs 150	600
7	Fertilizer cost	Fertilizer cost (NPK 70:24:24+ $ZnSO_4$ 25Kg/ha) Urea 380 kg @ Rs. 2.50/kg + SSP 375 @ Rs. 2/kg + Murate of potash Rs. 113 + $ZnSO_4$ Rs.150	1963	Fertilizer cost (NPK 175:60:60+ $ZnSO_4$ 25/kg/ha) Urea 380 kg @ Rs. 2.50/kg + SSP 375 @ Rs. 2/ kg + Murate of potash Rs. 115 + ZnSO4 Rs.150	1965
8	Weeding charges	20 labour for two hand weeding @ Rs. 135 and two tractor operated weeding @ Rs. 250	3200	20 labour for two hand weeding @ Rs. 135 and two tractor operated weeding @ Rs. 250	3200
9	Insect pest control	2 *Neem* oil @ 2.5 lit. = Rs. 500+ 1 Actara @150 ml =Rs 300 +Blitox @1.25kg = Rs 500+ Prophanopos 750ml (spot spray) = Rs.250	1550	2 *Neem* oil @2.5l =Rs. 500 + 1 Actara @60ml =Rs 300 +Blitox @1.25kg =Rs 500+ Prophanopos 250ml (spot spray) = Rs.250	1550
10	Thinning	3 labour @ Rs. 135	405	_	_
11	Picking cost	20 labour @ Rs. 135	2700	20 labour @ Rs. 135	2700
	Total expenditure		18573		27665
B.	**Production and income**				
1	seed cotton yield	25.85 q/ha @ Rs 3000/q	77550	30.5 q/ha @ Rs 3000/q	90750
C.	**Net income(B-A)**		**56977**		**63085**

On other side, with transplanting the farmers can save Rs. 1875/ha for seed which is required in less quantity for sowing in containers. The other expenditures are equal in both the system. While estimating the yield, the transplanted crop showed yield superiority of 4.40 q/ha and of transplanted crop was 30.25 q than 25.85 q in direct sown crop on date of transplanting. After deduction of expenditure the net income in direct sown crop was Rs. 56977 as compared to Rs. 63085 from transplated crop and higher net income Rs. 6108 / ha was observed (Table 2).

To study the role of seed index for improvement in plant stand, in hybrid CSHH 198, the plant stand percentage was significantly higher in seed lot with superior seed index (89.8%) than lower seed index (63.2%). In ungraded seed lot which is generally made available to the farmers for public bred varieties and hybrids, the germination per cent was 70.6 per cent which was also significantly lower than graded seed lot with superior seed index (89.8%). Similarly, in hybrid CICR 2, the germination percentage of superior seed index was significantly higher (87.2) than lower seed index seed lot (64.3). By improving the seed lot with superior seed index, improvement in plant stand 27 per cent in *G.hirsutum* and 14 per cent in *G.arboreum* was observed against ungraded mixed seed lot. The bolls/plant 47.7 and 53.9 was significantly higher in crop raised with superior seed index against with lower seed index 34.2 and 40.0 and ungraded mix seed lot 38.3 and 46.2 in hybrid CSHH 198 and hybrid CICR 2 respectively. In the crop raised using 9 and 8.5 g seed index lot in hy CSHH 198, the yield / ha 33.0 q and 30.3 q was observed which was significantly higher than 26.9 q/ha with the seed lot of lower seed index and 28.2 q/ha with mix seed index. Similarly in *G. arboreum* hybrid CICR 2, the yield in crop raised using seed lot with superior seed index (5.5 g), the yield of 32.6 q/ha was significantly higher than lower seed index seed lot (26.9 q/ha) and mix seed index lot (28.2 q/ha). Above 14 per cent increase in yield in *G.hirsutum* and 15 per cent in *G.arboreum* was observed in crop raised using superior seed index against mix seed lot. The monopodia, sympodia, plant height was significantly higher in crop with superior seed index (Table 3). William *et al.,* (2009) also reported 17 per cent more seedling emergence with 7 per cent more lint yield with the use of larger seed size than small seed size. The boll weight, ginning outurn, lint index and seed index were also recorded higher in crop of superior seed index in both the hybrids.

The pre sowing seed treatments were evaluated and significantly higher plant stand was observed in seed treated with KNO_3 100 mM + Imidacloprid + Vitavax 87.6 per cent than the control (water soaked seed) 82.8 per cent in CSHH 198 and in CICR 2 82.2 per cent than control (74.9%). The increase in plant stand with this treatment ranged from 6 per cent in *G.hirsutum* and 9 per cent in *G.arboreum,* respectively. The boll in these treatments was significantly higher than control in both the hybrids (Table 4). In CSHH 198, the significantly higher yield/ha (30.2 q) with KNO_3 100 mM + Imidacloprid + Vitavax followed by (29.7 q/ha), DAP 1 per cent + Imidacloprid + Vitavax and 29.4 q/ ha was observed significantly higher than control (27.8 q/ha). In CICR 2 also the yield (29.8 q/ha) with KNO3, (29.1 q/ ha) with DAP was significantly higher than control (27.5 q/ha). Above 8 per cent increase in yield in both the hybrids was observed. The difference for ginning outturn, seed index, boll weight and plant height were recorded non significant.

It is concluded that under north zone conditions upto 14 per cent higher plant stand could be obtained by transplanting of raised seedlings against normal sowing in *Bt* hybrid. Higher plant stand of 27 per cent in *G. hirsutum* and 14 per cent in *G. arboreum* with use of superior seed index against ungraded seed of non *Bt* hybrids was also observed. With improvement in plant stand, the increase in yield up to 26 per cent with transplanting of raised seedlings against normal sowing in *Bt* above 14 per cent in *G. hirsutum* and *G. arboretum* hybrids by using seed with superior seed index against ungraded seed and above 8 per cent with seed treatment with KNO3 imidacloprid, vitavax was observed. For increasing productivity, the crop can be advanced by raising seedlings in containers as the fields

Table 3. Role of seed index on plant stand and yield parameters in hy CSHH 198 and hy. CICR 2

Treatments	Germination (%)	Yield (q/ha)	Boll weight (g)	Boll/ plant	Ginning outturn	Seed index	Lint index
Hy. CSHH 198							
Seed index 9.0 (g)	89.8	33.0	3.6	47.7	34.7	9.3	4.9
Seed index 8.5 (g)	76.3	30.3	3.6	42.1	34.8	9.2	4.9
Seed Index 7.5 (g)	63.2	26.9	3.5	34.2	34.2	8.8	4.6
Control- mixed seed lot 8.2 g	70.6	28.2	3.7	38.3	24.0	9.2	5.0
CD at 5%	7.4	1.71	0.13	3.93	N.S.	N.S.	0.46
Hy. CICR 2							
Seed index 5.5 (g)	87.2	32.6	2.4	53.9	36.1	5.4	3.3
Seed index 5.0 (g)	76.6	30.0	2.4	46.6	36.3	5.2	3.2
Seed Index 4.5 (g)	64.3	26.6	2.4	40.0	35.8	4.8	2.9
Control- mixed seed lot 4.8 g	75.9	28.2	2.5	46.2	36.3	5.3	3.2
C. D. (p=0.05)	6.4	2.57	N.S.	4.75	N.S.	N.S.	N.S.

Table 4. Role of pre-sowing seed treatment on germination and yield in hybrid CSHH 198 and CICR 2

Treatments	Plant stand	Boll/ plant	Boll weight (g)	Yield/ ha(kg)	Plant height (cm)	GOT	Seed index	Lint index
Hy. CSHH 198								
KNO3 100mM+ Imidacloprid + Vitavax	87.6	47.5	3.6	30.2	124.5	35.7	9.1	5.1
KCl (2%) + Imidacloprid + Vitavax	83.7	46	3.5	28.7	116	35.4	8.7	4.8
DAP (1.0 %) + Imidacloprid + Vitavax	85.8	48	3.5	29.7	122.6	35.6	8.9	4.9
Water + Imidacloprid + Vitavax	84.7	46.1	3.5	28.0	114.9	35.5	8.7	4.8
Trichoderma	84.8	45.2	3.6	29.4	119	38.7	8.7	4.7
Control- Normal water for 6 h	82.8	44.4	3.5	27.8	111.8	35.4	8.6	4.7
CD (p=0.05)	6.7	1.6	NS	1.3	NS	NS	NS	NS
Hy. CICR 2								
KNO3 100mM+ Imidacloprid + Vitavax	82.2	52.5	3.6	29.8	109.1	36.6	8.5	4.9
KCl (2%) + Imidacloprid + Vitavax	77.8	49.5	3.6	28.6	103.2	36.2	8.3	4.7
DAP (1.0 %) + Imidacloprid + Vitavax	79.4	50.6	3.6	29.1	107.2	36.4	8.4	4.8
Water + Imidacloprid + Vitavax	75.8	48.9	3.5	28.2	102.2	35.9	8.3	4.7
Control- Normal water for 6 h	74.9	47.3	3.5	27.5	101.7	35.7	8.2	4.6
(p=0.05)	7.1	2.8	NS	1.20	4.1	NS	NS	NS

vacation generally gets delayed due to late harvesting of wheat crop or sowing of cotton is delayed due to late availability of canal water for pre sowing irrigation. Because of higher yield in transplanted cotton even after deduction of extra expenditure the net income of Rs. 6108/ha was higher.

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Combining ability analysis for yield and fibre quality traits in upland cotton (G*ossypium hirsutum* L.)

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Abstract : Six lines and nine testers were crossed and 54 hybrids were developed during *kharif,* 2006 to study seed cotton yield and fibre quality parameters. The parents, hybrids and three checks *viz.*, PHH 316, NHH 44 and Bunny were planted in *kharif,* 2007 at different locations. Observations recorded on 14 yield and yield contributing characters with an objective to estimate combining ability. The estimates of *gca* effects revealed that the parents PH 348, PH 1009, PH 1024 and PH 297-7-1 were found best general combiner not only for seed cotton yield/plant but also for other yield contributing characters in desired direction. In respect of specific combining ability the hybrids KH 121 x PH 1024, KH 120 x NH 545, KH 121 x PH 348 and PH 297-7-1 x PH 1024 had shown positive significant *sca* effects for seed cotton yield and its component traits.

Key words : Combining ability, cotton, *gca, sca*, yield

Cotton is one of the principal commercial crop in India. India is the largest cotton growing country in the world. Development of new varieties with high yield and better fibre properties is the primary objective of all cotton breeders. The first step in successful breeding programme is to select appropriate parents. Line x tester analysis provides a systematic approach for detection of appropriate parents and crosses in terms of investigated traits. The combining ability studies provide information on the genetic architecture of the parents as well as crosses, which is useful in developing a specific breeding strategy.

MATERIALS AND METHODS

The present investigation was under taken in *hirsutum* cotton involving six lines *viz.*, KH 120, DHY 286-IR, PH 297-7-1, KH 121, NH 572, and L 765 nine testers *viz.*, L 761, PH 348, PH 330, PH 44-1-2, PH 1009, PH 1024, NH 545, Cocker and MCU 5 of cotton genotypes having different characters. Fifty four hybrids (Six females and nine males) were developed by using the line x tester design in *kharif,* 2006. These lines, testers and hybrids along with three checks PHH 316, NHH 44 and Bunny were grown in randomized block design with two replications at Parbhani, Nanded and Badnapur in *kharif,* 2007. Row to row and plant to plant distances were maintained at 60 and 60 cm, respectively. Five competitive plants were randomly selected in each treatment/replication for recording the observations. The observations were recorded on days to 50 per cent flowering, plant height (cm), monopodia, sympodia and bolls/ plant, boll weight (g), ginning percentage, seed index, 2.5 per cent span length (mm), micronaire value (µg/inch), fibre strength (g/tex), fibre elongation, uniformity ratio and seed cotton yield/plant (g).

RESULTS AND DISCUSSION

The ratio of ä^2 *gca*/ ä^2 *sca* was less than unity for all the characters indicating predominance of non additive gene action for all the characters. General combining ability effects (Table 1) reveled that the parents MCU 5, PH 1009 and Cocker were good general combiners for earliness. The parents, PH 348, KH 121 and PH 330 were found best combiners for plant height. For monopodia/plant, KH 121, NH 545 and DHY 286-IR were best general combiners while the parents PH 348, L 765 and PH 330 were best combiners for sympodia/plant.

In respect of bolls/plant, parental lines PH 330, KH 121, PH 348 and PH 1024 were found best combiner. For boll weight the parent L 761 followed by PH 330 and DHY 286-IR had shown highest *gca* effect in desirable direction. Moreover the parents KH 120, PH 330 and Cocker were good general combiners for ginning percentage whereas, DHY 286-IR, PH 44-1-2 and

Table 1. Estimates of general combining ability (*gca*) effects of parents for various characters in cotton

Source of variation	Days to 50 per cent flowering	Plant height (cm)	Monopodia/ plant	Sympodia/ plant	Bolls/ plant	Boll weight (g)	Ginning (%)	Seed index (g)	2.5 per cent span length (mm)	Micronaire value (mg/in)	Fibre strength (g/tex)	Fibre elongation (%)	Uniformity ratio	Seed cotton yield/ plant (g)
Line														
KH 120	-1.20*	-2.33**	-0.09	-0.11	-0.6	0.16**	-1.33**	0.01	1.46**	-0.1	0.51**	0.07	-0.77	-0.51
DHY 286-IR	-0.98*	-0.28	-0.02	-0.39*	-0.77*	0	-0.86**	-0.13	-0.54*	0.17**	-	0.11*	0.32**	-4.33**
PH 297-7-1	0.15	2.74**	-0.07	0.28*	1.53**	-0.02	0.03	0.04	0.12	-0.16**	0.43**	0.25**	0.04	4.23**
KH 121	1.31*	0.56*	0.15*	0.15	-0.27	-0.21**	0.14	0.1	-0.05	-0.06	-0.34	-0.09	-0.13	-2.84
NH 572	0.26	-0.64*	0.02	-0.13	0.51*	-0.06	1.60**	-0.04	-1.19*	0.16**	-0.23	-0.36**	-0.78**	5.55**
L 765	0.46*	-0.04	0.02	0.2	-0.41	-0.14	0.42**	0.02	0.20*	0	-0.1	0.01	-0.24	-1.1
S.E. (gj) +	0.2	0.27	0.07	0.1	0.24	0.01	0.08	0.05	0.09	0.02	0.1	0.05	0.05	0.42
Tester														
L 761	-1.58**	2.56**	-0.13**	0.40**	0.82**	0.29**	-0.28	0.12	-0.36	0.06	0.95**	0.15	0.22	-1.2
PH 348	0.42**	1.01**	-0.02	-0.07	2.82**	0.07	1.05**	-0.21	-0.33	-0.09	-0.59**	-0.34*	-0.33	7.07**
PH 330	1.81**	1.51**	-0.02	0.01	-0.35	0.19**	-0.37	0.48	-0.95*	-0.01	-0.57**	-0.18	0.50**	2.01**
PH 44-1-2	-1.31**	1.53**	-0.10**	0.23	-1.04	-0.37	-0.46	-0.54	1.57**	-0.21	0.14	0.07	-0.52**	-3.99**
PH 1009	-0.39**	-0.88	-0.10**	0.48**	1.35**	0.21**	-0.89	-0.3	-0.15	0.11	0.26**	0	0.21	4.18**
PH 1024	1.61**	-0.88	0.18**	-0.16	0.23**	-0.02	0.82**	-0.27	0.52*	0.1	-0.66**	-0.37**	-0.49**	4.02**
NH 545	0.64**	-0.76	0.06**	-0.32	-2.07**	-0.03	-0.26	0.22	0.17	0	0.73**	0.33*	0.11	-8.50**
Cocker	0.28**	-2.26**	0.01	-0.32	-1.49**	-0.13	0.45	0.02	0.12	-0.06	-0.14	0.33*	0.21	-2.81**
MCU 5	-1.47**	-1.83*	0.12**	-0.24	-0.27	-0.22**	-0.06	0.47	-0.59*	0.09	-0.11	0	0.39**	-0.78
S.E. (gi) +	0.25	0.34	0.09	0.13	0.3	0.02	0.1	0.04	0.11	0.02	0.13	0.06	0.06	0.53

Table 2. Estimates of specific combining ability (*sca*) effects of hybrids for various characters in cotton

Sr. No.	Crosses	Days to 50 per cent flowering	Plant height (cm)	Monopodia/ plant	Sympodia/ plant	Bolls/ plant	Boll weight (g)	Ginning (%)	Seed index (g)	2.5 per cent span length (mm)	Micronaire value (mg/in)	Fibre strength (g/tex)	Fibre elongation (g)	Uniformity ratio	Seed cotton yield/ plant (g)
1	KH 120 x L 761	-2.05**	-2.47**	-0.07	-0.14	3.68**	0.05	-0.88**	-0.02	0.71**	0.13*	1.53**	0.34**	0.14	7.30**
2	KH 120 x PH 348	-2.55**	0.08	-0.02	0	-2.98	-0.34**	-1.88**	0.52**	-1.52**	-0.01	-0.91**	-0.17	0.50**	-9.89**
3	KH 120 x PH 330	-1.27*	-2.35**	-0.02	-0.75*	0.52	0.30**	2.20**	0.23*	0.3	-0.25**	-0.03	-0.11	-0.17	-6.61**
4	KH 120 x PH 44-1-2	4.18**	-5.38**	0.06	-0.14	1.88**	-0.21**	-0.52*	-0.2	-1.07**	-0.16**	-1.47**	0.01	0.58**	6.25**
5	KH 120 x PH 1009	4.59**	-1.69*	-0.1	-1.06**	-2.68	-0.01	0.56*	0.27*	1.09**	-0.24**	-0.16	0.26*	-0.88**	-6.07**
6	KH 120 x PH 1024	-1.07	-2.94**	-0.05	-0.25	-2.98	-0.29**	0.4	0.37**	0.81**	-0.13*	1.21**	0	-0.22	-10.34**
7	KH 120 x NH 545	1.23*	2.10**	-0.27	0.08	2.57**	0.19**	0.90**	-0.70**	-0.80**	0.45**	-0.61	-0.08	0.23	11.90**
8	KH 120 x Cocker	-0.57	6.63**	0.12	1.08**	-0.68	0.05	0.81**	-0.23*	0.87**	0.21**	-0.49	-0.38**	-0.65**	2.43*
9	KH 120 x MCU 5	-2.49**	6.02**	0.34	1.17**	0.6	0.26**	-1.59**	-0.24*	-0.39	0	0.93**	0.13	0.47**	-0.95
10	DHY 286-IR x L 761	0.73	-6.69**	0.02	-0.36	-1.82	0.26**	-1.48**	-0.31**	-0.38	0.55**	-0.15	1.00**	-0.17	0.05
11	DHY 286-IR x PH 348	-0.27	-1.87*	-0.09	-0.89*	-4.82	-0.46**	-0.62*	-0.48**	1.37**	-0.63**	-0.16	0.39**	-0.62**	-8.05**
12	DHY 286-IR x PH 330	1.84**	-1.37	0.24	-0.31	-1.32	0.25**	-2.37**	0.30**	0.02	0.48**	1.34**	0.34**	0.39**	-3.69**
13	DHY 286-IR x PH 44-1-2	-0.55	-3.40**	-0.18	-0.36	1.04	0.33**	0.22	-0.16	0.95**	-0.08	0.83**	-0.03	-0.01	-0.41
14	DHY 286-IR x PH 1009	-0.8	5.41**	-0.18	0.22	1.32	0.31**	-0.21	0.60**	-0.52*	-0.11	-0.26	-0.97**	0.41**	3.57**
15	DHY 286-IR x PH 1024	1.54**	1.84*	0.21	1.03**	2.10**	-0.29**	-0.08	0.08	-0.23	-0.30**	-0.44	-0.32*	-0.25	1.07
16	DHY 286-IR x NH 545	0.51	0.1	-0.01	-0.31	0.4	-0.61	1.07**	0.80**	-0.17	-0.02	0.21	0.25	0.44**	-5.65**
17	DHY 286-IR x Cocker	-2.30**	2.19**	0.21	0.01	2.32**	0.13**	2.50**	-0.2	-0.42	0.03	-1.51**	-0.61**	-0.04	9.55**
18	DHY 286-IR x MCU 5	-0.71	3.18**	-0.23	0.94**	0.77	0.08*	0.99**	-0.63	-0.62*	0.09	0.13	-0.04	-0.15	3.56**
19	KH 121 x L 761	-0.73	5.88**	0.07	0.31	-1.95	0.25**	0.28	0.69**	0.44	-0.44**	-0.90**	-0.47**	-0.29*	-7.34**
20	KH 121 x PH 348	-0.06	-6.55**	-0.2	-0.72*	1.89**	-0.05	-0.37	-0.05	2.62**	-0.1	2.85**	0.64**	-0.47**	11.86**
21	KH 121 x PH 330	0.05	-5.24**	-0.04	-0.31	2.22**	-0.02	-1.79**	0.31**	-0.57*	-0.22**	0.44	1.18**	0.28*	6.01**
22	KH 121 x PH 44-1-2	0.99	1.49	0.21	0.47	-1.42	-0.07	0.89**	0.55**	0.13	-0.09	-1.16	-0.27*	-0.50**	-6.61**
23	KH 121 x PH 1009	-2.09**	6.13**	-0.12	1.06**	3.19**	-0.29**	-0.05	-0.2	-0.80*	0.33**	0.93**	0.39**	0.79**	10.68**
24	KH 121 x PH 1024	2.41**	5.60**	0.1	0.03	2.80**	0.10**	0.37	-0.60**	-0.59*	0.50**	-0.48	-0.49**	0.12	14.08**
25	KH 121 x NH 545	-0.29	7.21**	0.05	1.69**	-1.89	0.54**	-0.94**	-0.86**	0.48	-0.55**	-0.36	-0.69**	-0.58**	-6.25**
26	KH 121 x Cocker	0.24	-10.96**	-0.06	-0.97**	-3.31	-0.60**	-0.53*	0.99**	-0.97**	0.40**	0.75*	0.13	0.60**	-19.89**
27	KH 121 x MCU 5	-0.51	-3.55**	-0.01	-0.56	-1.53	0.15**	2.13**	-0.83**	-0.75*	0.18**	-0.07	-0.42**	0.05	-2.53*
28	NH 572 x L 761	-2.73**	-2.68**	0.02	-0.73*	-0.15	-0.60**	0.21	-0.45**	-1.32**	0.36**	-0.68	0	0.47**	0.48
29	NH 572 x PH 348	3.27**	3.64**	0.24	0.74*	2.68**	0.45**	2.62**	-0.13	-1.50**	0.67**	-1.03	-0.16	0.27	6.39**

contd...

Table 2 contd...

30	NH 572 x PH 330	-1.12	1.64*	0.07	0.32	-1.98	-0.22**	-0.52*	0.52**	2.03**	-0.02	1.33**	0.48**	-0.48**	-6.94**
31	NH 572 x PH 44-1-2	-2.18**	5.37**	-0.01	0.44	1.04	0.63**	0.42	-1.08**	1.21**	0.17**	0.34	0.58**	-0.67**	-1.03
32	NH 572 x PH 1009	-3.93**	-6.86**	0.16	0.52	-0.85	-0.31**	-0.35	-0.14	-1.59**	-0.11	-1.58	-0.54**	0.15	-0.8
33	NH 572 x PH 1024	-1.07	0.85	-0.29	0.49	-1.73	0.45**	0.47*	-0.88**	-0.42	-0.14**	-0.34	0.33*	0.06	-8.20**
34	NH 572 x NH 545	0.55	-9.31**	-0.01	-1.33**	-1.6	-0.31**	-0.67*	1.36**	1.13**	-0.49**	0.63*	-0.03	-0.05	-2.85*
35	NH 572 x Cocker	1.24*	5.61**	-0.29	-0.18	2.32**	0.05	-2.13**	0.03	-1.88**	0.1	-0.26	-0.52**	0.54**	9.13**
36	NH 572 x MCU 5	3.82**	1.75*	0.1	-0.26	0.27	-0.14*	-0.06	0.78**	2.34**	-0.54**	1.59**	-0.15	-0.28*	3.82**
37	PH 297-7-1 x L 761	1.82**	3.59**	-0.02	1.05**	0.07	-0.13*	-0.87**	-0.01	1.32**	-0.34**	1.55**	-0.16	0.02	1.95
38	PH 297-7-1x PH 348	1.49*	-1.56	0.04	0.19	-0.1	0.14*	-0.90**	0.06	0.61*	-0.15**	-2.88**	-0.03	-1.40**	2.73*
39	PH 297-7-1x PH 330	-1.06	1.64*	0.04	0.94**	0.07	0.01	-0.23	-0.84**	-0.82**	-0.23**	-1.96**	-1.09**	0.06	-6.12**
40	PH 297-7-1x PH 44-1-2	-3.79**	-0.83	0.12	-0.45	0.27	-0.47**	-0.95**	0.25*	-1.73**	0.08	1.10**	-0.28*	1.06**	4.51**
41	PH 297-7-1x PH 1009	-1.04	-6.77**	0.12	-1.20**	-1.12	-0.20**	-0.23	-0.36**	1.14**	-0.1	1.63**	0.29*	-0.13	-5.69**
42	PH 297-7-1x PH 1024	-2.54**	8.84**	0.01	0.27	2.65**	0.28**	0.12	0.93**	-1.29**	0.14**	-0.65*	0.08	0.79**	9.54**
43	PH 297-7-1x NH 545	-0.23	6.88**	0.12	1.27**	-2.04	0.14**	2.76**	-0.61**	-0.83**	0.48**	0.16	0.46**	-0.25	-5.16**
44	PH 297-7-1x Cocker	2.46**	-6.22**	-0.16	-0.56	-0.46	-0.11*	1.37**	0.06	1.94**	-0.08	0.97**	0.34**	-0.84**	-1.95
45	PH 297-7-1x MCU 5	2.88**	-5.57**	-0.27	-1.48**	0.65	0.33**	-1.06**	0.54**	-0.34	0.19**	0.05	0.39**	0.69**	0.19
46	L 765 x L 761	2.95**	2.37**	-0.02	-1.12**	0.16	0.17**	2.74**	0.11	-0.76*	-0.26**	-1.36**	-0.70**	-0.60**	-2.45
47	L 765 x PH 348	-1.88*	6.26**	0.04	0.69*	3.33**	0.26**	1.16**	0.09	-1.59**	0.22**	2.13**	-0.67**	1.72**	-3.04**
48	L 765 x PH 330	1.59**	5.68**	-0.3	0.1	0.5	-0.32**	2.71**	-0.51**	-0.96**	0.24**	-1.12**	-0.80**	-0.08	11.36**
49	L 765 x PH 44-1-2	1.34*	2.75**	-0.21	0.05	-2.81	-0.22**	-0.05	0.64**	0.50*	0.08	0.37	0	-0.47**	-2.71
50	L 765 x PH 1009	3.26	3.79**	0.12	0.46	0.14	0.50**	0.28	-0.19	1.69**	0.24**	-0.57	0.56**	-0.33*	-1.69
51	L 765 x PH 1024	-1.41	-14.18**	0.01	-1.56**	-2.92	-0.25	-1.29**	0.1	1.71**	-0.07	0.69*	0.41**	-0.50**	-6.15**
52	L 765 x NH 545	-1.77*	-6.97**	0.12	-0.4	2.55**	0.05	-3.11**	0.02	0.19	0.14**	-0.02	0.08	0.2	8.02**
53	L 765 x Cocker	-1.07	2.76**	0.18	0.60*	-0.2	0.48**	-2.03**	-0.64**	0.46	-0.66**	0.53	1.03**	0.38**	0.73
54	L 765 x MCU 5	-2.99**	-2.45**	0.06	0.19	-0.75	-0.68**	-0.41	0.39**	-0.24	0.07	-0.63*	0.09	-0.77	-4.08**
	S.E. (gi) +	0.56	0.75	0.2	0.28	0.67	0.03	0.23	0.1	0.24	0.05	0.3	0.13	0.14	1.19

*, ** significant at 5 per cent and 1 per cent level, respectively

KH 121 were promising for seed index.

As regards the fibre quality the parents PH 1009, NH 545 and KH 121 were promising for 2.5 per cent span length, DHY 286-IR, PH 44-1-2 and KH 121 for micronaire value, PH 1009, PH 297-7-1 and KH 121 for fibre strength, PH 348, PH 1024 and PH 297-7-1 for fibre elongation and KH 120, NH 545 and NH 572 for uniformity ratio were good general combiners. The performance of the above parental lines for various traits was consistent across the environments.

The estimates of *gca* effects showed that the parent PH 348 was found best general combiner not only for seed cotton yield/plant but also for plant height, bolls/plant and ginning percentage. The parent PH 1009 was also found good general combiner for seed cotton yield/plant and other characters *viz.,* days to 50 per cent flowering, monopodia, sympodia and bolls/plant, boll weight and fibre strength. PH 1024 was best general combiner for seed cotton yield along with bolls/plant, ginning percentage and 2.5 per cent span length, while the parent PH 297-7-1 was best general combiner for seed cotton yield/ plant, plant height, sympodia, bolls/plant, micronaire value, fibre strength, fibre elongation and uniformity ratio. The results obtained are in accordance with Preetha and Raveendran, (2008), Patel *et al.,* (2009a), Patel *et al.,* (2009b), Deosarkar *et al.,* (2009), Singh *et al.,* (2010) and Kaliyaperumal (2010) reported different parents with good general combiners for seed cotton yield and yield contributing characters.

Specific combining ability (*sca*) effects were estimated for 14 characters for 54 crosses are presented in Table 2. The highly significant negative *sca* effect was observed in the cross NH 572 x PH 1009 for days to 50 per cent flowering. The cross PH 297-7-1 x PH 1024 recorded highly significant positive *sca* effect followed by KH 121 x NH 545 and PH 297-7-1 x NH 545 for plant height. The cross L 765 x PH 330 (-0.30) had expressed highest negative *sca* effect for monopodia/plant. For sympodia/plant the hybrids with high positive *sca* effects was KH 121 x NH 545.

In respect of bolls/plant, hybrids KH 120 x L 761 and L 765 x PH 348 were found best specific combiner. For boll weight the cross NH 572 x PH 44-1-2 exhibited highest positive significant *sca* effect followed by KH 121 x NH 545 and L 765 x PH 1009. Moreover the hybrids PH 297-7-1 x NH 545 and L 765 x L 761 were good specific combiners for ginning percentage whereas, NH 572 x NH 545 and KH 121 x Cocker were promising for seed index.

As regards the fibre quality the hybrids KH 121 x PH 348, NH 572 x MCU 5 and NH 572 x PH 330 were promising for 2.5 per cent span length. The hybrids L 765 x Cocker, DHY 286-IR x PH 348 and KH 121 x NH 545 had recorded negative and significant *sca* effects for micronaire value. The cross combinations KH 121 x PH 348, L 765 x PH 348 and PH 297-7-1x PH 1009 were found promising for fibre strength. The hybrids KH 121 x PH 330, L 765 x Cocker and DHY 286-IR x L 761 had recorded highly significant *sca* effect in desirable direction for fibre elongation. However, the cross L 765 x PH 348 exhibited highly significant *sca* effect for uniformity ratio. The hybrid KH 121 x PH 1024 had recorded positive significant *sca* effect followed by the cross combination *viz.,* KH 120 x NH 545 and KH 121 x PH 348 for seed cotton yield/plant.

Similar findings were reported by many workers *viz.,*Ahuja and Dhayal (2007), Lukonge *et al.,* 2007), Preetha and Raveendran (2008), Patel *et al.,* (2009a), Patel *et al.,* (2009b), Deosarkar *et al.,* (2009), Singh *et al.,* (2010), Kaliyaperumal (2010).

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Quantitative trait loci (QTL) analysis for yield and fibre quality traits in intra specific crosses of G*ossypium hirsutum* L.

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ABSTRACT : The identification and location of such polygenes or QTL with the help of molecular markers has the potential to provide characterization of quantitative traits. The QTL analysis was performed for yield and fibre quality traits on an experimental material consisting of 17 diverse lines crossed with 2 testers *viz.*, LH 900 and LH 1832, to produce 34 F_2 populations derived from triple test cross. The genotypic analysis identified 8 polymorphic RAPD markers generating 63 polymorphic loci among nineteen parental genotypes. The phenotypic and genotypic data for parents, used in single point association analysis revealed that all the traits under study except number of monopods/plant, plant height, length of sympod at 50 per cent plant height (sympod at the middle of the main stem), days to maturity, seed cotton yield and fibre fineness were associated with different loci. Association analysis performed in F_2 generation of triple test cross progenies identified one putative QTL for node number of first monopod, number of bolls at sympod at 50 per cent plant height (sympod at the middle of the main stem), lint yield and fibre maturity. Four putative QTL were detected for seed index and 3 for ginning outturn. Implication of this study to identify genes mediating quantitative characters has been discussed.

Key words: Fibre fineness, fibre length, fibre strength, RAPD markers, triple test cross, upland cotton

Majority of the economically important characters are inherited quantitatively which are presumed to be controlled by large number of genes with small and cumulative effects. The exact number and location of these genes with the help of genetic analysis is difficult to estimate. The identification and location of such polygenes with the help of molecular markers has the potential to provide analysis of quantitative characters. The molecular markers are increasingly being used in crop improvement since they are not influenced by the environmental conditions and unlike morphological markers can be made available in large number. Molecular tagging of quantitative trait loci (QTL) and their transfer into elite genetic backgrounds is one of the most important applications in plant breeding. QTL have been identified for agronomic and fibre quality traits in cotton using RFLPs (Ulloa and Meredith, 2000; Shapley *et al.*, 1998). Efforts were made to identify more QTL for yield and fibre traits, so that systematic breeding work can be undertaken for their improvement. In the present study attempts has been made to identify RAPD markers and QTL's associated with different yield and fibre quality traits in *Gossypium hirsutum*.

The present investigation was carried out in the experimental area of Cotton Section, Department of Plant Breeding and Genetics and the laboratory work in the Molecular Biology Laboratory of Department, Entomology, Punjab Agricultural University, Ludhiana. The experimental material consisted of 17 genetically diverse genotypes particularly for 2.5 per cent span length *viz.,* CNH 1012, CNH 123, RS 992, RS 2013, RS 2059, RS 2060, LH 1990, LH 1991, LH 1992, LH 1993, Senegal, LRA 5166, LRK 516, RS 875, G Cot 16, LH 1972 and LH 1980. The 2 testers namely, LH 900 and LH 1832 with divergent fibre qualities were crossed with each of the 17 lines to produce 34 F_1s. Nineteen parental lines along with 34 F_2 populations were grown in the field. The experimental material was grown with two rows each of the parental lines and four rows of F_2 populations in a randomized complete block design with 3 replications. Recommended cultural practices were followed to raise a good crop. The field data were recorded for number of monopods and sympods/plant, node number of first monopod, node number of first sympod, plant height, length of first sympod, length of sympod at 50 per cent plant height, bolls at sympod at 50 per cent plant height, days to maturity, seed cotton yield/plant, bolls/plant, boll weight, seed index, lint index, lint yield/plant, ginning outturn, 2.5 per cent span length, fibre fineness, fibre strength, fibre uniformity ratio, fibre maturity and fibre quality index.

PCR amplifications were carried out using random 19 different decamer RAPD primers from operon technologies. All PCR reactions were performed in a pre standardized reaction mixture of 25 il volume. Total of 8 markers namely, OPF 02, OPH 9, OPF 07, OPE 02, OPB 05, OPB 10, OPE 01 and OPC 04 showing polymorphism between the parents were selected for further screening the population. The data on molecular markers were recorded in binary fashion *i.e.* the present band was designated as one and the absent band was marked as zero. Thereafter, single point analysis was performed on both genotypic and phenotypic data using Macintosh based QGene software version 2.26 (Nelson, 1997), which yields information on association of markers loci with the genes controlling the phenotypes. QGene uses simple regression to examine all the marker loci in the data. The dependent variable is the trait score and the independent one is the marker allele in the parental lines. The marker showing statistically significant association was presumed to be the putative QTL for the trait of interest. Since the set of parental lines was not derived from a cross of two homozygous lines so it did not constitute a mapping population required in traditional QTL analysis. In such an association analysis, some of the putative QTL are expected to be a reflection of purely statistical association rather than linkage of markers and genes. The data on L_{1i} and L_{2i} progenies were thus used to make a rough distinction between linkage and statistical association. For every marker showing significant association, the single marker analysis was also performed on the basis of $[1/2(L_{1i} + L_{2i})]$ and $[1/2(L_{1i} - L_{2i})]$ to estimate additive and dominance gene effects of putative QTL. A true QTL was inferred to be located near the fragment, which showed both the associations in parental lines and additive and/or dominance effects from the analysis of L_{1i} and L_{2i} families.

The identification of QTL requires a suitable mapping population to prepare a linkage map of available molecular markers. Each of these markers is then assessed for possible linkage with the genes controlling the character under consideration to locate the position of such QTL and to estimate their genetic effects. In the present study only a set of unrelated lines was analyzed by PCR amplification of random DNA fragments through RAPD primers. Irrespective of their map location, these fragments were then examined through association analysis to find a possible association of each polymorphic fragment with the genes mediating the characters under investigation. On the basis of extent of polymorphism, out of 19 random decamer primers screened, 8 primers were selected. The selected primers produced 62 fragments out of which 42 fragments were polymorphic. The average number of bands *i.e.* differential fragments produced/primer, were 4.65 with the range of 2-7 bands/genotype. The genotypic and the phenotypic data were associated using single point association analysis carried out on QGene version 2.26' (Nelson, 1997). As a result variable numbers of loci were identified to be associated with different yield and fiber quality traits at 5 and 1 per cent level of significance. Only the loci showing statistically significant association in parental lines have been listed for yield and fibre traits in Table 1. In addition to parental lines their L_{1i} and L_{2i} progenies of triple test cross were also evaluated to estimate additive $[1/2(L_{1i} + L_{2i})]$ and dominance $[1/2(L_{1i} - L_{2i})]$ components of variation for these traits. The loci with significant association in parental lines were further evaluated for possible additive $[1/2(L_{1i} + L_{2i})]$ and dominance $[1/2(L_{1i} - L_{2i})]$ components of variation. The loci showing significant association in both parental lines and with additive and /or dominance effects were inferred to be the putative QTL. The association of these loci with yield components and fibre quality traits for sums $[1/2(L_{1i} + L_{2i})]$ and for differences $[1/2(L_{1i} - L_{2i})]$ are presented in Table 1.

One or more loci were found to be associated with all yield and earliness characters except for monopods, plant height, length of sympod at 50 per cent plant height, days to maturity and seed cotton yield (Table 1). The fibre traits like lint yield/plant, ginning outturn, lint index, 2.5% span length, fibre strength, fibre uniformity ratio, fibre maturity and fibre quality index, had significant association with some of the amplified fragments. Fibre fineness was the only character where none of the fragment showed significant association with any amplified fragment.

The association analysis among the parental lines revealed six loci, *viz.,* m61, m52, m58, m31, m5 and m35 to be associated with number of sympods, which accounted for 46 to 21 per cent of the variation for this trait (Table 1). However, none of these loci showed association with this trait in the association analysis for sums [$1/2(L_{1i} + L_{2i})$] and differences [$1/2(L_{1i} - L_{2i})$]. Only one locus, m30 was found to be associated with node number of first monopod and explained 26 per cent of the trait variation (Table 1). The association analysis for sums revealed this locus to be associated with node number of first monopod and explained 47 per cent of the trait variation. Thereby, suggesting this locus to be the putative QTL for node number of first monopod (Table 1). Locus m54 was found to be associated with node number of first sympod and explained 23.1 per cent of the variation for the trait (Table 1). However, the association analysis for sums and differences could not reveal this locus to be associated with this trait. Similarly, for length of first sympod, two loci viz, m9 and m35 explained 22.4 and 21.9 per cent of the variation for this trait respectively, however, they were not statistically associated with additive and/or dominance gene effects for this trait.

The association analysis in parental lines showed only one locus m61 to be linked with number of bolls at first sympod and explained 30 per cent of the variation for this trait, however the association analysis for sums and differences did not indicated any association for this trait. The association analysis in parental lines revealed seven loci *viz.,* m53, m59, m60, m58, m52, m24 and m41 to be associated with bolls on sympod at 50 per cent plant height. Among these loci, m53, m59 and m60 explained 28 per cent of variation for the trait, m58 and m52 each explained 21 per cent of the variation whereas loci m24 and m41 explained 25 and 24 per cent of the variation for the trait respectively. Out of these only m41 locus was found to be associated with dominance [$1/2(L_{1i} - L_{2i})$] effects of this trait (Table 1). Thus, it is likely to be a putative QTL for bolls on sympod at 50 per cent plant height. For bolls/plant, two loci namely, m41 and m31 were found to be associated with the trait and explained 58.8 and 29.5 per cent of the variation for the trait, respectively. However, none of these loci were found to be associated with this trait in the association analysis for sums and differences. Similarly, five loci, namely, m23, m56, m53, m59 and m60 were found to be associated with boll weight as indicated by association analysis of parental lines. Among these m56 and m23 explained 41 and 34 per cent of the variation for the trait, respectively whereas m53, m59 and m60, explained 26 per cent of total variation for the trait of interest. However, the association analysis for sums [$1/2(L_{1i} + L_{2i})$] and differences [$1/2(L_{1i} - L_{2i})$] could not reveal any of these 5 loci to be associated with boll weight. For seed index, six loci viz, m35, m41, m61, m31, m24 and m12, explained 22 to 29 per cent of the variation for the trait as indicated by association analysis of parents. Among these, m35, m41, m61 and m31 were found to be associated with additive gene effects. Since all of these 4 loci were amplified by different RAPD markers, these loci could be inferred as 4 putative QTL for seed index. Only one QTL with additive gene effects was identified for seed index (Shapley *et. al.*, 1998), however, He *et. al.,* (2007) identified 8 QTL for this trait.

In case of lint yield and lint index, only one locus m41 was observed to be associated with these traits and explained 22.6 to 27 per cent of the trait variation, respectively. But the association analysis for sums [$1/2(L_{1i} + L_{2i})$] and differences [$1/2(L_{1i} - L_{2i})$] showed significant association with additive gene effects for lint yield only, and explained 35 per cent of the trait variation (Table 1), thereby, suggesting it to be the putative QTL for lint yield. Ulloa and Meredith (2000) identified two QTL for lint yield whereas He *et al.,* (2007) identified 11 QTL for this trait. However, for lint index, the association analysis for sums and differences could not identify any fragment to be associated with this trait. But Shappley *et al.,* (1998) identified one QTL with additive and dominance gene effects, Ulloa and Meredith (2000) identified three QTL and He *et. al.* (2007) identified four QTL for lint index. The single point association analysis for ginning outturn identified seven loci namely, m22, m35,

Table 1. Association of PCR amplified fragments with yield, fibre quality and their component traits

Sr No	Character	Fragments	Association with parents		Association for sums		Association for differences	
			R^2	P	R^2	P	R^2	P
1	Number of sympods	m61	0.46**	0.001	0.085	0.522	0.001	0.990
		m52	0.39**	0.004	0.088	0.522	0.001	0.990
		m58	0.39**	0.004	0.088	0.522	0.001	0.990
		m31	0.32*	0.012	0.167	0.276	0.022	0.853
		m5	0.30*	0.016	0.145	0.333	0.002	0.980
		m35	0.21*	0.046	0.0	1.0	0.052	0.684
2	Node number of first monopod	m30	0.26*	0.02	0.473*	0.011	0.065	0.622
3	Node number of first sympod	m54	0.22*	0.04	0.006	0.958	0.086	0.532
4	Length of first sympod (cm)	m9	0.22*	0.04	0.211	0.189	0.319	0.067
		m35	0.21*	0.04	0.026	0.820	0.082	0.547
5	Bolls at first sympod	m61	0.3*	0.02	0.0	1.0	0.123	0.396
6	Bolls at sympod at 50 per cent plant height	m53	0.28*	0.02	0.004	0.970	0.297	0.084
		m59	0.28*	0.02	0.004	0.970	0.297	0.084
		m60	0.28*	0.02	0.004	0.970	0.297	0.084
		m24	0.25*.	0.03	0.148	0.324	0.002	0.980
		m41	0.24*	0.03	0.339	0.054	0.476*	0.010
		m58	0.21*	0.05	0.167	0.276	0.056	0.665
		m52	0.21*	0.05	0.167	0.276	0.056	0.665
7	Bolls/plant	m41	0.56**	0.0001	0.184	0.240	0.054	0.677
		m31	0.29*	0.0162	0.066	0.617	0.273	0.106
8	Boll weight (g)	m56	0.41**	0.003	0.0	1.0	0.0	1.0
		m23	0.34**	0.008	0.237	0.149	0.001	0.990
		m53	0.26*	0.025	0.045	0.724	0.031	0.797
		m59	0.26*	0.025	0.045	0.724	0.031	0.797
		m60	0.26*	0.025	0.045	0.724	0.031	0.797
9	Seed index (g)	m35	0.29*	0.02	0.431*	0.019	0.001	0.990
		m41	0.28*	0.02	0.578**	0.002	0.018	0.879
		m61	0.23*	0.04	0.368*	0.039	0.0	1.0
		m24	0.23*	0.04	0.056	0.665	0.030	0.805
		m12	0.22*	0.04	0.347	0.050	0.069	0.065
		m31	0.22*	0.04	0.361*	0.043	0.069	0.065
10	Lint yield/plant (g)	m41	0.23*	0.039	0.350*	0.047	0.004	0.970
11	Ginning outturn (%)	m22	0.41**	0.003	0.270*	0.015	0.379**	0.002
		m35	0.39**	0.004	0.190	0.219	0.047	0.710
		m61	0.36**	0.006	0.400**	0.001	0.077	0.569
		m2	0.26*	0.024	0.230*	0.030	0.0	1.0
		m27	0.25*	0.039	0.021	0.860	0.012	0.915
		m56	0.23*	0.039	0.0	1.0	0.0	1.0
		m12	0.21*	0.049	0.041	0.743	0.001	0.993
12	Lint index (g)	m41	0.28*	0.02	0.166	0.279	0.004	0.970
13	2.5 per cent span length (mm)	m20	0.27*	0.028	0.329	0.060	0.086	0.532
		m41	0.23*	0.039	0.187	0.232	0.004	0.970
14	Fibre strength (g/tex)	m49	0.24*	0.034	0.0	1.0	0.0	1.0
15	Fibre uniformity ratio	m24	0.36**	0.006	0.004	0.970	0.013	0.914
16	Fibre maturity	m9	0.37**	0.004	0.366*	0.040	0.421*	0.022
17	Fibre quality index	m49	0.39**	0.004	0.007	0.951	0.006	0.961

*,** significance at 5 and 1 per cent level of significance, respectively.

m61, m2, m27, m56 and m12 to be associated with the mean performance of the trait and explained 40.9 to 20.8 per cent of the variation of ginning outturn (Table 1). Among these seven loci, the association analysis for sums and differences revealed locus m22 to be associated with both additive and dominance gene effects whereas the loci m2 and m61 were observed to be associated with only additive gene effects. All these three loci are thus likely to be putative QTLs controlling ginning outturn.

In case of fibre quality traits, the analysis revealed 2 loci namely, m20 and m41 to be associated with 2.5 per cent span length and explained 26.6 and 22.6 per cent of total variation for the trait, respectively. However, the association analysis for sums [$1/2(L_{1i} + L_{2i})$] and differences [$1/2(L_{1i} - L_{2i})$] did not identified any loci to be associated with this trait (Table 1). Depending on the population, different number of QTL for fibre length have been reported, e.g., 2 (Ulloa and Meredith, 2000); 3 (Kohel *et al.,* 2001); 5 (He *et al.,* 2007). Only one locus m49 was found to be associated with both fibre strength and fibre quality index explaining 23.7 and 39 per cent of the trait variation, respectively (Table 1). However, the association analysis for sums [$1/2(L_{1i} + L_{2i})$] and differences [$1/2(L_{1i} - L_{2i})$] did not identify this locus to be associated with any of these traits. But three QTL have been identified for fibre strength by Ulloa and Meredith (2000), Zhang *et al.*, (2003) and He *et al.,* (2007) and while 4 QTLs for bundle strength were reported by Kohel *et al.,* (2001). Similarly, single point analysis for uniformity ratio revealed single locus, m24, to be associated with this trait and explained 36 per cent of the trait variation. However, the association analysis for sums [$1/2(L_{1i} + L_{2i})$] and differences [$1/2(L_{1i} - L_{2i})$] could not establish any association for this locus for the uniformity ratio. For fibre maturity also, the association analysis revealed single locus m9 to be associated with this trait, which explained 38 per cent of the variation for this trait (Table 1). The association analysis further identified this locus to be associated with both additive (sums) and dominance (differences) gene effects for this trait and explained 36.6 and 42 per cent of the trait variation, respectively. Thus, this locus is likely to be a putative QTL for fibre maturity.

In the present investigations some loci were found to show association with more than one trait in the parental population. The single point analysis in parents identified locus m41 to be associated with bolls/plant, seed index and bolls at sympod at 50 per cent plant height, which explained 56, 28 and 24 per cent of the trait variation, respectively (Table 1). Similarly, locus m35 was found to be associated with number of sympods, length of first sympod and seed index and explained 21, 21 and 29 per cent of the variation for the respective traits. Locus m61 was found to be associated with number of sympods, number of bolls at first sympod and seed index, and explained 46, 30 and 23 per cent of variation for the trait respectively (Table 1). Two loci, m52 and m58 were found to be associated with sympods and bolls at sympod at 50 per cent plant height and explained 39 and 21 per cent of the trait variations, respectively. Similarly, single

Table 2. Characteristics of markers associated with yield and fibre quality traits

Designation of DNA fragments	RAPD primer number	Base pairs	Associated traits based on $L_{1i}+L_{2i}$ and $L_{1i}-L_{2i}$
m2	OPF 02	1850	Ginning outturn
m5	OPF 02	500	
m9	OPH 9	1500	Fibre maturity
m12	OPH 9	800	
m20	OPF 07	1031	
m22	OPF 07	600	Ginning outturn
m23	OPF 07	400	
m24	OPE 02	1900	
m27	OPE 02	650	
m30	OPE 02	400	Node number of first monopod
m31	OPE 02	250	Seed index
m35	OPB 05	700	Seed index
m41	OPB 10	1031	Seed index, lint yield, bolls at sympod at 50 per cent plant height
m49	OPC 04	2000	
m52	OPC 04	1000	
m53	OPC 04	850	
m54	OPC 04	750	
m56	OPC 04	650	
m58	OPC 04	550	
m59	OPC 04	400	
m60	OPC 04	350	
m61	OPC 04	300	Seed index, ginning outturn

point analysis identified three loci namely, m53, m59 and m60 to be associated with boll weight and number of bolls at sympod at 50 per cent plant height. Each of these loci explained 28 and 26 per cent of the variation of boll weight and bolls at sympod at 50 per cent plant height, respectively. Another loci m31 showed association with sympods, bolls/plant and seed index, which explained 32, 29 and 22 per cent of the trait variation, respectively (Table 1). Similarly, single point analysis in parents identified m24 to be associated with bolls at sympod at 50 per cent plant height and seed index and explained 25 and 23 per cent of the variation for the respective traits. The single point association analysis for fibre traits in parents identified locus m41 to be associated with lint yield, lint index and 2.5 per cent span length, and explained 22.6, 27.9 and 22.6 per cent of the variation of these respective traits. Locus m49 showed association with fibre strength and fibre quality index, and explained 23.7 and 39.3 per cent of the variation of these traits, respectively (Table 1).

The present study was only an exploratory attempt to identify specific segments of DNA, which may represent the location of genes mediating quantitative characters of economic importance in Upland cotton. Eight RAPD markers were observed to amplify specific fragments of complementary sequences, which were polymorphic among set of parental lines. The 2 markers *viz.,* OPB 05 and OPB 10 amplified only one fragment each whereas marker OPF 02 and OPH 09 amplified two fragments each (Table 2). Three polymorphic loci were identified using marker OPF 07, four by marker OPE 02 and nine by marker OPC 04 (Table 2). The fragments amplified by each marker may represent distinct loci or multiple alleles of any specific marker. Due to an unknown ancestry of experimental material it is difficult to make a distinction between these two propositions. A perusal of total variation explained by each fragment amplified by a particular marker for many of the characters does not support the label of each locus and an individual marker. The allelic status of multiple loci amplified by any marker is expected to be correlated on explaining the magnitude of total variation accounted for by all loci as a result of which total R^2 values exceeds the maximum value of 100. It was thus attempted to identify loci associated with additive and/or dominance effects of genes controlling the character under investigation. The loci so identified have been labeled as putative QTL which need to be confirmed from analysis of proper QTL mapping population.

A simultaneous quantitative genetic analysis and QTL mapping was adopted to assess the scope of finding real QTL from the association of such randomly amplified DNA fragments. Though the number of markers producing polymorphic loci was limited but considerable part of available genetic variation was observed to be associated with these loci. The marker OPB 10 identified a loci with strong association with lint yield. Similarly, marker OPH 09 appears to have a strong complimentarity with gene for fibre maturity. The practical implications of this study need to be confirmed from an analysis of mapping population derived from a cross of two parents. It was mainly an exercise to assess the possibilities of using routine breeding materials for mapping genes in quantitative traits for their possible use in marker assisted selection. The preliminary observations suggest that such an exercise is possible and can be made more meaningful by using already mapped polymorphic markers so that their breeding potential may be evaluated before starting any cotton breeding strategy. It however, remains to be confirmed by typical QTL mapping analysis of proper mapping population derived from the material under investigation.

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Performance of some newly developed *Bt* cotton hybrids under rainfed condition of Marathwada region

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ABSTRACT : Performance of some newly developed *Bt* cotton hybrids was evaluated during *kharif,* 2010. Out of 20 hybrids tested, five hybrids recorded significantly higher seed cotton yield over high yielding check, Bunny BG I. Majority of the hybrids recorded low values for fibre tenacity which reflected into lower values for fibre strength / length ratio (<0.80). There is need for improvement of fibre tenacity in relation to fibre length for obtaining better quality of yarn.

Key words : Adaptability, *Bt* hybrid cotton, fibre tenacity, productivity gains, S/L ratio

Cotton production and productivity has almost doubled since 2003 and farmers have economically benefitted from increase in net income. *Bt* cotton hybrids occupy about 90 per cent of cotton acreage which has shown increasing trend. Large number of *Bt* cotton hybrids developed by number of private seed companies have been approved for commercial cultivation. There is need for extensive testing of the hybrids for identifying region specific suitable hybrid for recommending to farmers. This will help to boost up further cotton production and sustain productivity gains. With this objective in mind, some newly developed *Bt* cotton hybrids were evaluated for yield and fibre quality under rainfed condition of Marathwada region.

The field experiment was conducted during *Kharif,* 2010 at Cotton Research Station, Nanded. In all, 24 *Bt* cotton hybrids including four checks *viz.*, Bunny BG I, Bunny BG II, RCH 2 BG II and Atal BG II were tested in randomized block design with three replications. The net plot size was 3.6 x 6.0 m^2 with four rows of each hybrid. Spacing between rows and plants was maintained at 90 and 45 cm, respectively. The soil of experimental field was medium black cotton soil having pH range of 7.2 to 8.0, low in nitrogen, medium in phosphorus and high in potash content. The total rainfall received during the season was 1440.6 mm which was 63.6 per cent above average rainfall. Seed cotton yield and ginning outturn were recorded on plot basis. The fibre quality parameters were evaluated at CIRCOT Unit, Guntur.

Seed cotton and lint yield : Seed cotton yield of *Bt* cotton hybrids ranged between 1091 to 1845 kg/ha. Out of 20 test entries five hybrids *viz.,* MRC 7383 BG II, NCS 8899 BG II, PRCH 733 BG II, PRCH 31 BG II and NCS 1914 *Bt* recorded significantly higher seed cotton yield over higher yielding check, Bunny BG I (1365 kg/ha). These hybrids gave 22.7 to 35.1 percentage higher seed cotton yield over superior check, Bunny BG I. Bunny BG I and Bunny BG II recorded statistically *at par* seed cotton yield (Table 1). Rajamani *et al.*,(2009) observed 8.81 to 33.59 per cent heterosis for seed cotton yield. Patel *et al.*,(2011) reported 9.84 to 46.00 per cent standard heterosis for seed cotton yield. Kumar *et al.*,(2013) reported 68.98 percent highest economic heterosis for seed cotton yield. Lint yield of *Bt* cotton test hybrids ranged between 413-703 kg/ha. Three hybrids *viz.,* NCS 8899 BG II, PRCH 733 BG II and MRC 7383 BG II recorded significantly higher lint yield over checks, Bunny BG I and Bunny BG II. The above three hybrids seem promising since they have given best performance for seed cotton yield and lint yield as well. Performance of *Bt* cotton hybrids

Ginning outturn : Ginning outturn of hybrids ranged between 35.08 - 41.72 per cent. Four test hybrids *viz.,* DPC 5061 BG II (41.72%), MRC 7373 (40.19%) PRCH 31 BG II (39.95%) and PRCH 733 (39.92%) recorded significantly higher ginning outturn than higher ginning check hybrid, Bunny BG II (38.99%).

Fibre quality parameters :

Span length (2.5 %) : Most of the hybrids depicted superior medium to long staple and the value ranged between 26.6 – 30.9 mm (Table 2).

Uniformity ratio (%) : Uniformity ratio of hybrids ranged between 45-52%. Most of the hybrids had value nearer to checks, Bunny BG I and Bunny BG II.

Micronaire value : The values ranged between 3.9 – 4.5 and were *at par* with checks.

Fibre tenacity (g/tex) : The fibre tenacity ranged between 19.3 – 23.0 Majority of the hybrids depicted values closer to checks, Bunny BG I and Bunny BG II. Low to medium heterosis for fibre strength has been reported by Patil *et al.*,(2012).

Fibre strength / length (S/L) ratio : Most of the hybrids had low values for fibre tenacity in relation to their fibre length. The value for fibre strength / length ratio was below desired one (0.80). Large scale cultivation of recommended hybrids will help to boost up cotton production. Quantity and quality wise genetic improvement of Indian cotton is at most required to remain globally competitive and sustain productivity gains.

Table 1. Seed cotton and lint yield, ginning outturn and fibre quality parameters of new *Bt* cotton hybrids tested in SAU trial

Hybrid	Seed cotton yield (kg/ha)	Increase over Bunny BG I (%)	G.O.T. (%)	Lint yield (kg/ha)	2.5 per cent SL (mm)	UR (%)	MIC	Tenacity 3.2 mm (g/tex)	S/L ratio
NCS 8899 BG II	1830*	34.0	38.42	703*	28.2	50	4.5	20.9	0.74
NCS 1914 *Bt*	1675*	22.7	36.24	607	30.5	49	4.3	22.7	0.74
NCS 459 BG II	1634	19.7	35.54	580	29.9	50	4.4	22.9	0.76
NCS 913 BG II	1091	-	37.92	413	28.8	51	4.3	22.5	0.78
NCS 908 BG II	1358	-	37.16	504	29.2	50	4.3	23.0	0.78
PRCH 732 BG II	1612	18.0	35.42	570	30.9	48	4.2	22.5	0.73
PRCH 733 BG II	1720*	26.0	39.92**	686*	26.7	49	4.1	19.3	0.72
PRCH 31 BG II	1704*	24.8	39.95**	680	26.6	52	4.1	19.3	0.72
PRCH 708 BG II	1499	9.8	39.42	590	27.8	51	4.1	21.0	0.75
MRC 6304 *Bt*	1257	-	36.99	464	28.8	49	4.0	20.8	0.72
MRC 7017 BG II	1389	1.7	38.61	536	29.7	46	3.9	20.6	0.69
DPC 5061 BG II	1202	-	41.72**	501	29.2	45	4.0	19.7	0.67
DPC 7065 BG II	1307	-	37.43	489	30.6	49	4.0	21.7	0.71
MRC 7373 BG II	1349	-	40.19**	542	29.3	48	3.9	20.6	0.70
MRC 7383 BG II	1845*	35.1	37.18	685*	29.1	50	4.0	22.2	0.76
PCH 1411 *Bt*	1609	17.8	36.59	589	28.9	48	4.1	22.6	0.78
PCH 2270 *Bt*	1620	18.6	36.87	597	29.0	50	4.0	22.7	0.78
PCH 360 BG II	1378	0.9	35.08	483	30.0	48	3.9	22.5	0.75
PCH 1411 BG II	1512	10.7	36.78	556	29.6	49	4.0	22.6	0.76
PCH 1410 BG II	1272	-	38.43	488	30.5	49	4.1	22.6	0.74
Bunny BG I (Ch)	1365	-	37.66	514	31.9	45	4.5	20.5	0.64
Bunny BG II (Ch)	1316	-	38.99	513	30.6	47	4.2	22.9	0.75
RCH 2 BG II (Ch)	1096	-	37.05	406	28.8	46	4.0	20.9	0.73
Atal BG II (Ch)	1301	-	37.96	493	30.9	44	3.9	20.9	0.67
C.D. (p=0.05)	271	-	0.89	170					
C.V. (%)	12.08	-	1.47	14.1					

* Indicates significant over check, Bunny BGI, * * Indicates significant over check, Bunny BGII

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Genetic divergence for morpho physiological traits in upland cotton

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ABSTRACT: Genetic diversity of 40 genotypes of cotton was assessed using Mahalanobis D^2 statistic for 21 characters which indicated considerable diversity in the material. The 40 genotypes were grouped into 8 clusters. Nine characters *viz.*, crop growth rate at 60-120 DAS followed by bolls/plant, boll weight , leaf area index at 120 DAS, seed cotton yield/plant, specific leaf weight, days to 50 per cent flowering, sympodia/ plant, plant height and uniformity ratio contributed maximum towards genetic divergence. The mutual relationships between the clusters revealed that inter cluster distance values were greater than intra cluster values. The inter cluster distance between clusters IV and VI was maximum and the genotypes from these clusters may be utilized in breeding programmes for seed cotton yield improvement.

Key words: Cotton, D^2 statistic, genetic divergence

Cotton (*Gossypium spp.*) popularly called "White Gold" is the most important renewable natural fibre crop of global importance and is the mainstay of India's economy. This is because *per se* performance of a parent is not always true indicator of its potential in hybrid combination. Hybrids between genotypes of diverse origin display a greater heterosis and minimize the inherent field genetic vulnerability than those hybrids involving closely related parents .So, in the present study to attain genetic upgrading and sustainability, access is made for diversity present in 40 genotypes both for morphological and fibre quality traits by employing Mahalanobis D^2 statistics. It has been extensively used as a quantitative measure to identify diverse genotypes.

The experiment was conducted during *kharif,* 2010-2011 in randomized block design with 40 germplasm lines obtained from all over India with three replications following spacing of 120 x 60 cm at Agricultural College Farm, Bapatla. Recommended doses of fertilizers were applied in split doses. Each plot consisted of two rows of 6m length and observations were recorded on five randomly selected plants from each genotype/replication for 21 characters *viz.,* plant height (cm), sympodia and bolls/plant, boll weight (g), seed index (g), lint index (g), ginning outturn (%), specific leaf weight (mg/cm^2), relative water content (%), leaf area index, crop growth rate (g/m^2/day).The data on days to 50 per cent flowering, ginning outturn (%), bundle strength (g/tex), uniformity ratio, 2.5 per cent span length (mm), micronaire (10^{-6}g/in), uniformity ratio and fibre elongation (%) were recorded on plot basis.

Analysis of variance indicated sufficient variability in the material under study indicating considerable genetic diversity among 40 genotypes. The knowledge on characters influencing divergence is an important aspect to a breeder. The maximum contribution towards genetic divergence was by crop growth rate at 60-120 days (28.85) followed by bolls/plant (21.25), boll weight (15.50), leaf area index at 120 DAS (6.98), seed cotton yield/plant (5.77), specific leaf weight (4.62), days to 50 per cent flowering (2.82), sympodia/plant (2.38), plant height (2.31), uniformity ratio (2.31), ginning outturn (1.28), fibre elongation (1.15), micronaire (0.15), harvest index (1.03), lint index (1.02), specific leaf weight at 120 DAS (0.64), 2.5 per cent span length (0.51), seed index (0.51), relative water content at 120 DAS (0.51) and relative water content at 60 DAS (0.31) Characterwise rank has shown that no single character lonely had a greater contribution to total genetic divergence. Further analysis was done by using Mahalanobis D^2 statistics.

On the basis of relative magnitude of D^2 values all the 40 genotypes were grouped into 8 clusters. Maximum number of genotypes were included in cluster I (19 genotypes) from different locations. They are T_x lama, 11760-30, G COT 16, ICMF 23, Rai 123, ADB 10050, CRH 71, JK 20-6, CCH 16, K 153, Khandwa 2, SFA 5, L 766, CPD 431, AET 5, HLS 323, ICMF 86, LH 1566, NA

Table 1. Average intra-and inter-cluster D^2 values among eight clusters in 40 cotton genotypes (*Gossypium hirsutum* L.)

Cluster No.	I	II	III	IV	V	VI	VII	VIII
I	**52.587(7.25)**	104.270	86.875	74.759	116.384	203.601	203.903	243.521
II		**76.869(8.77)**	178.773	191.244	171.551	120.184	195.605	242.379
III			**0.000(0.00)**	91.639	107.466	265.410	136.136	208.418
IV				**0.000(0.00)**	155.898	326.925	263.051	296.100
V					**113.081(10.63)**	189.997	181.592	193.904
VI						**0.000(0.000)**	143.531	168.137
VII							**0.000(0.000)**	175.228
VIII								**0.000(0.00)**

Note: Bold and diagonal values indicate intra cluster D^2 distance; figures in parentheses are D values

Table 2. Mean values of eight clusters estimated by Tocher's method from 40 genotypes of cotton (*Gossypium hirsutum* L.)

Cluster No	Days to 50% flowering	Plant height (cm)	Sympodia/ plant	Bolls/ plant	Boll weight (g)	Ginning outturn (%)	Seed index (g)	Lint index (g)	2.5per cent span length (mm)	Mic. (10^{-6} g/in)	Bundle strength (g/ tex)	Uniformity ratio	Fibre elongation (%)	C.G.R at 60-120 days (g/m^2/ day)	RWC at 60 DAS (%)	RWC at 120 DAS (%)	SLW at 60 DAS (mg/ cm^2)	SLW at 120 DAS (mg/ cm^2)	LAI at 120 DAS	Harvest index	Seed cotton yield/ plant (g)
1	56.035	95.398	14.232	22.202	3.345	36.066	8.928	5.037	27.666	4.515	21.029	50.182	5.835	2.802	83.144	84.491	5.810	6.027	**1.753**	0.301	74.231
2	53.905	92.432	15.064	22.594	**4.530**	37.402	9.392	5.624	26.893	4.690	20.829	50.100	5.801	3.389	83.181	85.310	5.826	5.887	2.165	0.363	101.955
3	**53.667**	**77.227**	11.067	24.947	**2.393**	34.797	8.377	4.767	26.540	4.747	22.133	**52.200**	6.050	4.260	**69.000**	83.605	5.277	**5.380**	2.153	**0.243**	**58.787**
4	**61.333**	105.110	17.633	26.600	2.537	**31.023**	**9.710**	**4.367**	**28.630**	**4.317**	21.067	49.800	**6.147**	**2.623**	86.205	86.495	**6.787**	**6.320**	2.303	0.277	68.617
5	55.852	94.533	13.726	**22.025**	2.852	33.660	8.981	4.633	**26.324**	4.517	20.887	51.016	5.480	4.310	82.885	85.948	5.635	6.031	2.547	0.260	62.615
6	58.333	107.617	**18.567**	24.567	4.310	**42.713**	**7.560**	5.633	27.753	4.447	21.367	49.900	**5.430**	5.603	**87.147**	**91.777**	5.387	6.250	**3.453**	**0.367**	**104.027**
7	55.333	**121.647**	15.633	26.050	2.690	40.183	9.033	**6.067**	27.477	**5.367**	**22.767**	51.100	5.900	**8.070**	85.163	86.845	**5.227**	5.517	2.137	0.307	71.273
8	59.000	82.360	**10.433**	**29.070**	3.220	33.777	8.633	4.700	27.180	4.873	**20.300**	**25.710**	5.500	6.523	81.907	**81.110**	5.617	5.887	2.507	0.360	92.623

Note: Bold figures are minimum and maximum values

1560.Cluster VII was the second largest with 11 genotypes *viz.,* 4084, CCH 727, JK 4, LH 960, JK 206-2, *G.ageti,* JK 345 . It is followed by 9 genotypes *viz.,* Pee DEE 0113, CNH 7-947, GSHY 01/1338, CSH 17,GJHV 302, CIPRAN 2361, ICMF 83, ARB 8901, ARB 815 in cluster V, 7 genotypes *viz.,* 4084, CCH 727, JK 4, LH 960, JK 206 2, G.ageti, JK 345 in cluster II. Clusters III, IV, VI, VII and VIII were solitary clusters with genotypes TSH 333, NA 1584, TCH 1218, K 390 2 and TCH 1599 respectively showing nil intra cluster D^2 values. The formation of distinct solitary clusters may be due to the fact that geographic barriers preventing gene flow or intensive natural and human selection for diverse and adoptable gene complexes must be responsible for this genetic diversity. The pattern of grouping of genotypes into different clusters was random and indicated that there is no parallelism between genetic divergence and geographical divergence of genotypes. Therefore, selection of genotypes for hybridization should be based on genetic diversity rather than geographical diversity. This was in accordance with the results of Preetha and Raveendran (2008), Eswara Rao *et al.,* (2009), Gopinath *et al.,* (2009), Rajamani and Mallikarjuna Rao (2009), Venkateswarulu *et al.* (2010) and Srinivasulu *et al.* (2010).

The average intra- and inter cluster D^2 values are presented in Table 1. The inter-cluster distance was maximum between clusters IV and VI (326.93) while it was minimum between the clusters V and VIII (193.90) suggesting that there is wide genetic diversity between these clusters. Based on these studies, crosses can be attempted between the genotypes of these clusters to obtain desirable transgressive segregants. Higher mean values for boll weight were seen in cluster II (4.53) and VI (4.31) and higher means for boll plant were observed in clusters IV (26.60), VII (26.05) and VIII (29.07) which are major contributors in improving seed cotton yield/plant in cotton (Table 2). Based on mean values, series of crosses in diallel analysis may prove highly successful for improving fibre quality and quantity.

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Correlation and path analysis studies in *Gossypium arboreum* L.

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ABSTRACT: Sixty genotypes of *Gossypium arboreum* were evaluated to study the characters association and path effects. The correlation studies revealed that days to first flower, plant height, bolls/plant, monopods, boll weight and seed index showed significant and positive correlation with seed cotton yield/plant. The associations of bolls/plant and boll weight with seed cotton yield/plant were stronger than remaining yield traits. Path analysis revealed positive direct effect of days to first flower, bolls/plant, boll weight and lint index on seed cotton yield. Bolls/plant and boll weight had high positive direct effect on seed cotton yield/ plant and appeared to be the most important component of yield. Direct selection for these two traits could prove advantageous for improving seed cotton yield.

Key words: Correlation, *Gossypium arboreum,* path analysis, seed cotton yield

Cotton is the world's most important fibre crop and plays a vital role in social and economic affairs of the world. Among cotton growing countries of the world, India has lowest productivity. The genetic improvement of yield and its component traits in crop plants is the principal breeding objectives. In order to increase the yield potential of cotton, an understanding of the relationship among different yield contributing characters is of immense importance. A breeder is more concerned with improvement of yield, which is an overall product and dependent on a number of component traits. The interrelationship among such component characters is also a vital importance. Knowledge about the direct and indirect contribution of different traits to seed cotton yield would be highly useful for formulating a selection criteria. Therefore, the present investigation was carried out for generating information on correlation and path analysis of different attributes in *Gossypium arboreum*.

The present investigation was carried out in Research Area, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar during *kharif,* 2011. Sixty diverse cotton genotypes from different cotton growing states were raised in a randomized block design (RBD) in 3 replications. There were 2 rows of each genotype of 3 m length. Rows were spaced 67.5cm apart and plant to plant distance with in a row was 30 cm. The data were recorded on 5 competitive plants selected randomly from each replication. The mean of 5 plants was used for statistical analysis. The data on the 9 parameters were recorded *viz*, days to first flower, plant height (cm), monopods, bolls/plant, boll weight (g), seed cotton yield/plant (g), ginning outturn (%), seed index (g) and lint index (g). Genotypic and phenotypic correlations were worked out.

Pesual of data in Table 1 showed that mostly the correlation coefficients among the various characters at the genotypic level were greater than their corresponding phenotypic ones indicating thereby that inspite of a strong inherent association between the various traits studied, the phenotypic expression of correlation was lessened under the influence of enviroment. Seed cotton yield/plant had highly significant and positive correlation with its component characters *viz.* bolls/plant, boll weight, days to first flower, plant height, number of monopods and seed index, while positive non significant association with lint index. Therefore, by improving these characters there are possibilities of improvement in yield. Muthuswamy *et al., (*2004) for plant height, bolls/ plant, boll weight and seed index.These attributes were interelated with each other which indicated that improvement in these traits could bring about substantial increase in seed cotton yield.

Significant and positive associations were also observed between component characters themselves like that of plant height with number of bolls per plant, boll weight, seed index and lint index which was in conformation

Table 1. Phenotypic (above diagonal) and genotypic (below diagonal) correlations among various yield and its attributing traits

	Days to first flower	Plant height	Bolls/ plant	Monopods	Boll weight	Ginning outturn	Seed index	Lint index	Seed cotton yield/ plant (g)
Days to first flower	**1.000**	-0.077^{NS}	0.159*	0.208**	0.286**	0.258**	0.245**	0.366**	0.272**
Plant height	-0.093^{NS}	**1.000**	0.278**	-0.202**	0.202**	-0.070^{NS}	0.247**	0.107**	0.255**
Bolls/plant	0.170*	0.307**	**1.000**	0.260**	0.241**	0.028^{NS}	0.087^{NS}	0.089^{NS}	0.788**
Monopods	0.245**	-0.243**	0.290**	**1.000**	0.077^{NS}	0.236**	-0.067^{NS}	0.148*	0.208**
Boll weight	0.322**	0.234**	0.300**	0.100^{NS}	**1.000**	-0.108^{NS}	0.253**	0.096^{NS}	0.641**
Seed cotton yield/plant	0.291**	0.302**	0.881**	0.229**	0.692**	-0.057^{NS}	0.154*	0.070^{NS}	**1.000**
Ginning outturn	0.352**	-0.129^{NS}	0.080^{NS}	0.413**	-0.173*	**1.000**	-0.100^{NS}	0.777**	-0.069^{NS}
Seed index	0.322**	0.312**	0.078^{NS}	-0.086^{NS}	0.376**	-0.297**	**1.000**	0.537**	0.222**
Lint index	0.533**	0.124^{NS}	0.145^{NS}	0.297**	0.165*	0.713**	0.448**	**1.000**	0.138^{NS}

* Significant at 5%, **Significant at 1%

Table 2. Direct (diagonal) and indirect (off diagonal) effects of yield components on seed cotton yield at genotypic level

	Days to first flower	Plant height (cm)	Bolls/ plant	Monopods	Boll weight (g)	Ginning outturn (%)	Seed index (g)	Lint index (g)	Genotypic Correlation with seed cotton yield
Days to first flower	**0.065**	0.004	0.127	-0.008	0.142	-0.103	-0.065	0.129	0.291
Plant height	-0.006	**-0.041**	0.234	0.008	0.104	0.037	-0.063	0.029	0.302
Bolls/plant	0.011	-0.012	**0.763**	-0.009	0.133	-0.023	-0.016	0.034	0.881
Monopods	0.016	0.010	0.221	**-0.031**	0.045	-0.120	0.018	0.070	0.229
Boll weight	0.021	-0.009	0.229	-0.003	**0.443**	0.050	-0.077	0.038	0.692
Ginning outturn	0.023	0.005	0.061	-0.013	-0.076	**-0.295**	0.060	0.166	-0.069
Seed index	0.021	-0.012	0.059	0.003	0.166	0.085	**-0.204**	0.104	0.222
Lint index	0.036	-0.005	0.110	-0.009	0.073	-0.208	-0.091	**0.232**	0.138

with the finding of Annapurve *et al.,* (2007), Leelapratap *et al.*, (2007) and Muthuswamy *et al.,*(2004). bolls/plant had significantly positive association with monopods and boll weight confirms the earlier findings Kaushik *et al.*, (2003), Neelam and Potdukhe (2002) and Annapurve *et al.,* (2007). Similarly boll weight is significant and positive association with seed index as reported by Muthuswamy *et al.,* (2004) and Annapurve *et al.,* (2007).

Association of various characters is the consequence direct and indirect effects of different characters. It becomes imperative to partition such association into direct and indirect effects of component character through path analysis. Path analysis (Table 2) showed that the direct effects of bolls/plant was found to be highly positive (0.763) on seed cotton yield. These results confirm the earlier findings of Leelapratap *et al.,* (2007) and Salahuddin *et al.,* (2010).

Boll weight also had high positive and direct effect on seed cotton yield/plant (0.442) and its indirect effect was through bolls/plant (0.230). Positive direct effect was reported by Muthu *et al.*, (2004) and Salahuddin *et al.*, (2010).

Days to first flower had negligible positive direct effect on seed cotton yield/plant (0.065) and it exhibited low positive indirect effect *via* boll weight (0.142), lint index (0.129) and bolls/ plant (0.127). Similar result was reported by Ashokkumar and Ravikesavan (2010).

A positive direct effect of lint index on seed cotton yield/plant was observed (0.232). Similar findings were also reported by Leelapratap *et al.*, (2007).

Ginning out turn showed highest negative direct effect (-0.295) on seed cotton yield per plant, followed by seed index (-0.204), plant height (-0.04) and number of monopods (-0.03). These finding were in conformity with those of Annapurve *et al.,* (2007) for ginning outturn, seed indexand monopoda.

Selection for high seed cotton yield seems to be possible through bolls/plant and boll weight as they exerted high positive direct effect as well as had highly positive and significant association with seed cotton yield.

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Development of GIS and GPS based spatial cotton fibre quality maps for Nagpur district of Maharashtra

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ABSTRACT : A case study was carried out to design and develop Geographical Information System (GIS) and Geographical Positioning System (GPS) based spatial cotton fibre quality maps for Nagpur district of Vidharbha region of Maharashtra. Spatial database and spatial fibre quality maps for parameters such as 2.5 per cent span length, uniformity ratio, fineness, strength, elongation, ginning percentage, short fibre content, degree of reflectance and degree of yellowness were developed. Spatial distribution, classification and characterization of the district based on the fibre quality were carried out to provide site specific information. The quality features of the cotton grown in Nagpur district was analyzed by visualizing the spatial maps. The 2.5 per cent span length of the cotton was observed to fall in two classes, *i.e.* long and extralong, and the uniformity ratio into three classes, *i.e.*, average, good and excellent. The fineness of the cotton could be categorized into three classes namely, very fine, fine and average. The strength of the cotton was found between good and very good. It was observed that cotton grown in moderately deep to deep clayey soil are of extralong staple with average fineness, good strength and lower short fibre content. Cottons grown in very shallow to shallow loamy soils were of long staple, and fine with average strength and higher short fibre content. Cotton produced in plains was found to have higher staple, fineness and strength compared to those produced at higher elevations. It is concluded that spatial maps would be highly useful to traders, ginners, researchers and industry for efficient planning and decision making process.

Key words: Cotton, fibre quality, GIS, GPS, spatial maps

With the global shift towards market economics, the need for timely, reliable and location specific information has become more important. A comprehensive knowledge of the spatial cotton quality parameters is of fundamental importance to cotton traders and industry for efficient planning of their business. Cotton is being traded in the market based on its variety and grade. First hand spatial information related to cotton grown and its quality parameters is not available. Even if available, it is represented in tabular forms and it is difficult to interpret and visualize the variations and assess the availability of particular quality of cotton in the district, region or state.

Recently emerged technologies like Geographic Information System (GIS) and Geographical Positioning System (GPS) are widely used as spatial analysis tool for effective and efficient means of data acquisition, data storage and retrieval, manipulation and analysis and output generation (Baily, 1990). A GIS offers many advantages for spatial data management and presentation, including a structured representation for data, data management functions, and most importantly, visualization of data. Spatial simulations can take advantage of large quantities of data previously digitized as GIS layers. (Mccauley, 1999). It provides continuous surfaces from point data. Spatial distribution, classification and characterization of the region are possible with GIS based on any phenomenon. It helps to analyze trends over time, and spatially evaluate impacts caused by development. GIS allows developing decision making processes much faster (Bantalan *et al.,* 2000)

A GIS combines geographic mapping capabilities with a database management system. A GIS database consists of a set of data layers, usually referencing a common coordinate system, which describe different thematic or quantitative information. Applying GIS to the process of preparing crop estimates has improved accuracy while lowering costs (Fourie, 2008).

Application of Global Position System (GPS) and Geographic information system (GIS) to provide accurate, key and important information for decision making and planning of cotton crop mapping crop was made in Keneya. GIS based spatial analysis was conducted and the best locations for harvest collection centres were determined, based on the shortest and least cost path of delivery by the farmer. The maps produced have proven to be critical tools for the field officers for route planning when conducting field visits. This has led to a considerable cut in the cost of production (Felix, 2011)

To circumvent this problem, a case study was carried out and to develop GIS and GPS based spatial fibre quality maps for cotton grown in Nagpur district of Vidhartbha region of Maharashtra. Spatial fibre quality maps would be useful for classification of the area under cotton based on fibre quality. Spatial maps provide site specific information. As visual interpretation of information in the form of maps allows finding variations quickly, these maps would be highly useful to traders, ginners, policy makers and researchers for systematic planning of their interest for the particular area or the region.

Seed cotton samples from spatial locations were collected by using Geographical Positioning System (GPS) from the cotton growing area of Nagpur district by following stratified sampling method. In stratified sampling method the population is divided into sub/populations (strata) and random samples are taken of each stratum in a number proportional to the stratum's size when compared to the population. The longitude, the latitude and the elevation of the locations were noted. A GPS instrument-Magellan Triton 200 was used for recoding the spatial locations. The study was carried out during the crop season 2009-2010. A total of 306 samples were collected from Nagpur district. The spatial locations were widely distributed and representative of the study area with predominantly grown cotton varieties. Secondly spatial locations were recorded from the sampling area by using GPS (Fig. 1).

The samples were ginned on the Lilliput gin developed by CIRCOT. The ginned samples were tested on High Volume Instrument (HVI-900) for measurement of fibre quality. Digitization and geo-referencing of the toposheets of Nagpur district were carried out. The non-cotton growing area was delineated from the cotton growing area.

The spatial database and the spatial fibre quality maps for parameters namely 2.5 per cent span length, uniformity ratio, fineness, strength, elongation, ginning percentage, short fibre index (SFI), degree of reflectance (Rd) and degree of yellowness (+b) were prepared. Spatial distribution, classification and characterization of the Nagpur district based on each fibre quality were carried out. These spatial fibre quality maps were correlated with the soil maps, such as soil depth and soil texture.

Table 1. Taluka wise samples collected from Nagpur district

S. N	Taluka	No. of Spatial Locations
1	Parsioni	53
2	HIngna	36
3	Narkhed	49
4	Ramtek	19
5	Katol	41
6	Saoner	48
7	Kalmeshwar	43
8	Kamptee	17
	Total	**306**

Fig. 1. Recording of spatial location by using GPS

GIS based spatial fibre quality database and maps : Fibre quality and GPS data of spatial locations obtained from the sampling area was analyzed and depicted in Table 2.

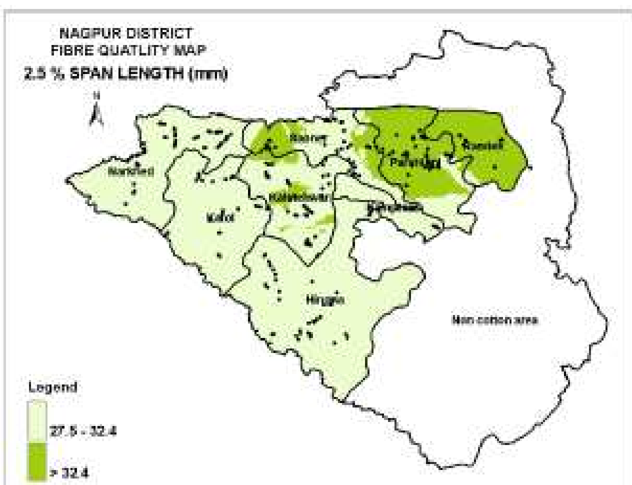
The spatial database and maps for fibre quality parameters was developed using ARCGIS software. Significant variation in fibre quality parameters among the different talukas were observed in Nagpur district. Spatial database and spatial fibre quality maps for parameters such as 2.5 per cent span length, uniformity ratio, fineness, strength, elongation, ginning percentage, short fibre index (SFI), degree of

Table 2. Variation in the fibre quality parameters in Nagpur district

Parameter	Min	Max	Average
Logitude	78.24.17 E	79.23.04 E	—-
Lattitude	20.54.33 N	21.50.55 N	—-
Location Elevation(m)	204	324	**318**
GP (%)	27.2	40.9	**33.1**
Fibre length (mm)	24.0	36.4	**30.7**
Uniformity ratio (%)	39	54	**48**
Fineness (mic)	2.2	5.6	**3.6**
Strength (g/tex)	17.7	27.5	**23.6**
Elongation (%)	3.6	6.4	**5.0**
SFI (%)	3.5	14.6	**6.1**
Rd (%)	54.3	84.8	**77.4**
+b (%)	4.6	10.8	**7.7**

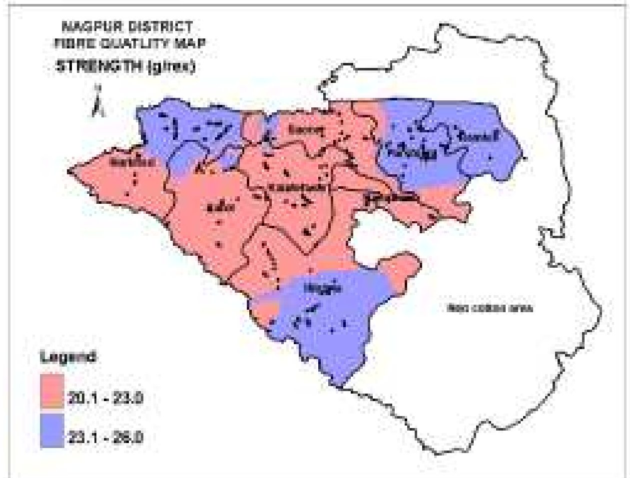
reflectance (Rd) and degree of yellowness (+b) were prepared. The spatial maps of Nagpur district for different fibre quality parameters are shown below (Fig. 2).

Spatial distribution, classification and characterization of the Nagpur district based on the fibre quality were carried. The quality features of the cotton grown in Nagpur district was analyzed by visualizing the spatial maps (Table 3).

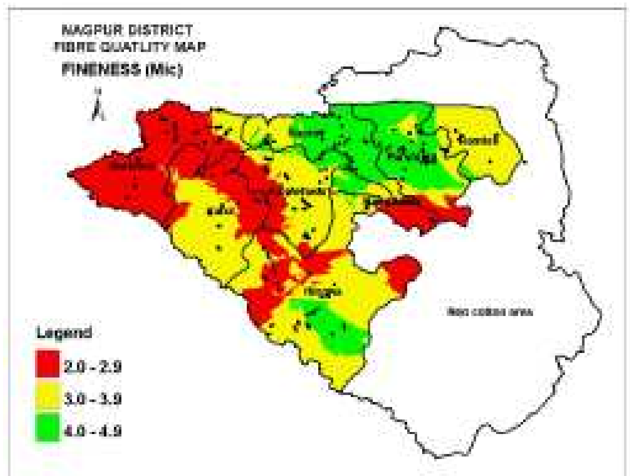


(a) Spatial map for 2.5 per cent Span Length

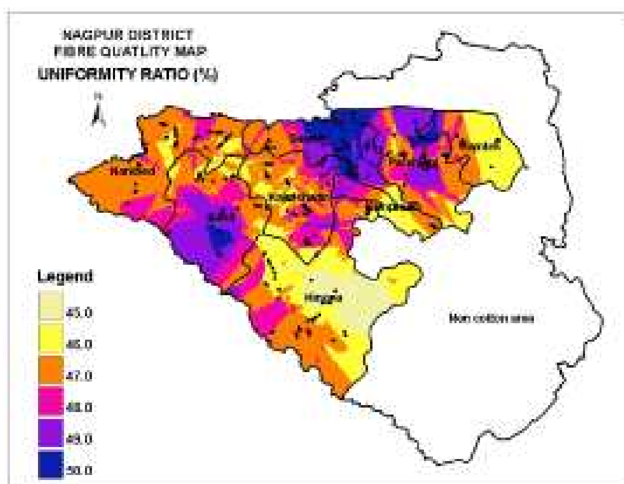
The features of the cotton grown in Nagpur district that was observed by looking at the maps were, staple of the cotton was found to be long and extra long, uniformity ratio was observed to be from average to excellent, fineness between very fine to average and the strength good to very good.



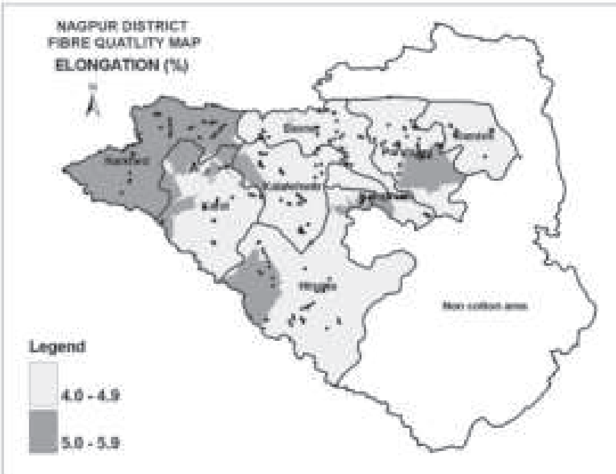
(b) Spatial map for fibre strength



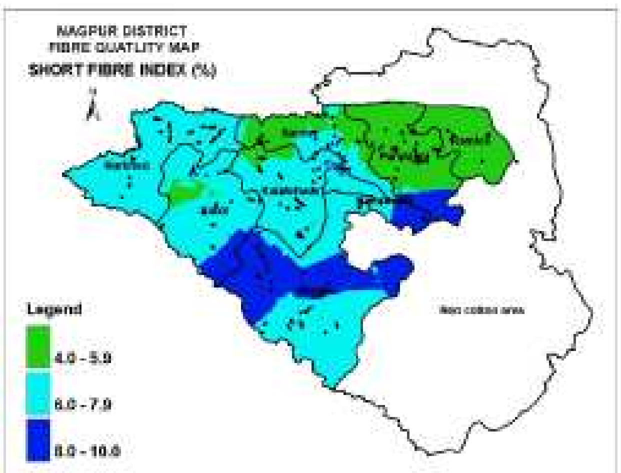
(c) Spatial map for fineness



(d) Spatial map for uniformity ratio



(e) Spatial map for elongation



(f) Spatial map for short fibre content

Fig 2. Spatial fibre quality maps for Nagpur district

Table 3. Fibre quality of cotton as visualized form spatial maps

Fibre quality parameter	Classification	Range
2.5 percent span	Extra-long	> 32.5
length (mm)	Long	27.5-32.5
Uniformity Ratio (%)	Excellent	> 47
	Good	45-46
	Average	44-45
Fineness (mic)	Very Fine	< 3.0
	Fine	3.0-3.9
	Average	4.0-4.9
Strength (g/tex)	Very Good	> 26.1
	Good	23.1-26.0

Correlation of spatial fibre quality maps with soil maps : The soil depth, the soil texture and the elevation maps of the Nagpur district were prepared in the GIS environment (Fig. 3 and Fig 4). The soil depth maps of the cotton growing area were delineated from the non-cotton growing area. The soil in the study area was found to be clayey and loamy based on the depth of soil. Further based on the texture, the soil in study area was found to be deep, moderately deep, moderately shallow, shallow, very shallow and extremely shallow. The elevation of the study area was found between 245 to 470 m.

The cotton produced in Nagpur district was found to be of long and extra-long staple. 2.5 percent span length was found between 28.1 to 33.9 mm. Cotton produced in the deep clayey soil

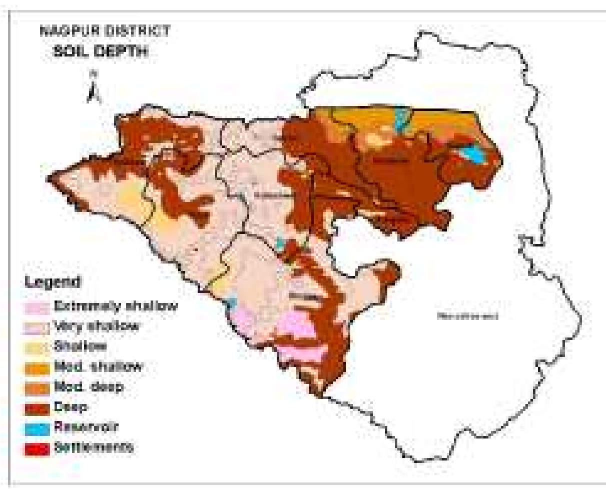


Fig 3. Soil depth map for Nagpur district

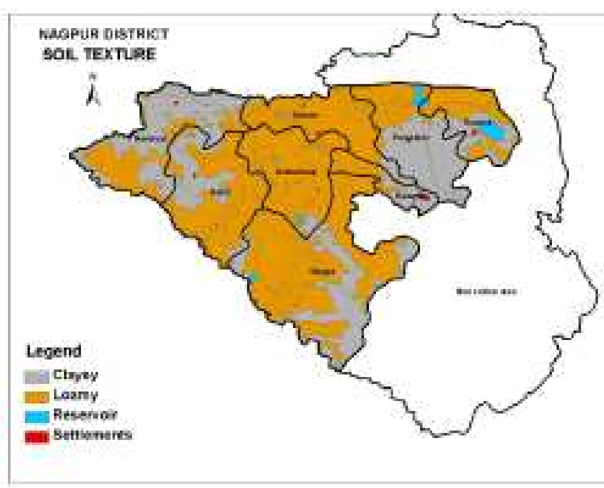


Fig 4. Soil texture map for Nagpur district

Table 4. Cotton fibre quality with respect to soil type

Soil type	Fibre Quality
Moderately deep to deep clayey	Extra long staple, average fineness, good strength and lower short fibre content.
Very shallow to shallow loamy	Long staple, fineness of fine category, with average strength and comparatively higher short fibre content.

was found to be extra long type. In loamy soil, the long staple cotton was mostly grown. At higher elevations, fibre length of the cotton was found to lower compared to the cottons in the plains.

The fineness of cottons produced in this region was found between 2.9 to 4.2 mic. In moderately deep to deep clayey soil, fineness was found to be of average category and ranged between 4.0-4.9 mic. In shallow loamy soils, the fineness was observed in the fine category and ranged between 3.0-3.9 mic. At higher elevations in clayey soil, the fineness of the cotton was found below 3.0 mic. At higher elevations fineness of the cotton was found to be comparatively lower than the cottons in the plains.

The fibre strength of the cottons produced in this region was found to range from 20.2 to 26.0 g/tex. In moderately deep to deep clayey soil, strength was found to be of good category ranging from 23.1 to 26.0 g/tex. In shallow loamy soils, the strength of the cotton was observed in the average category and ranged from 20.1 to 23.0 g/tex. At higher elevations, strength was found to be a bit lower than the cottons in the plains.

The percent fibre elongation was found better in clayey soils than loamy soils. In clayey soils, it was found to range from 5.0 to 5.9 per cent and in loamy soils 4.0 to 4.9 per cent. The short fibre content of the cotton produced in this region was found to vary from 4 to 10 per cent. Cottons in loamy soils found to have short fibre content of 6.0 to 7.9 per cent and in clayey soils 4.0 to 5.9 per cent. Cottons produced in clayey soils were found to have lower short fibre content than the cottons in loamy soils.

CONCLUSIONS

- The spatial distribution, classification and characterization of the Nagpur district based on the fibre quality were found to be very effective in visualization and interpretation of the data.
- The 2.5 per cent span length of the cotton was observed to fall in two classes i.e. long and extra long, uniformity ratio was found into three classes' *i.e.* average, good and excellent, Fineness falls in three classes namely, very fine, fine and average and the strength between good and very good.
- Definite trend in fibre quality with soil type was noted as visualized.
- Spatial maps found to be useful to traders, ginners, researchers and industry for efficient planning and decision making.

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Effects of nutrients and spacing on productivity of *Bt* cotton hybrids

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Abstract: A field experiment was conducted at Punjab Agricultural University, Regional Research Station, Faridkot during *kharif,* 2010 and 2011. The treatments comprised of three *Bt* cotton hybrids (*i.e.* MRC 7361, Bioseed 6488 and RCH 134) in main plot, two plant geometries (*i.e.* 67.5 x 75 and 67.5 x 90 cm) in sub and three nutrient levels (*i.e.* 100% recommended [Rd] (150kg N, 30kg P/ha); (125% of Rd and 150% of Rd) in sub sub plots of split plot design replicated thrice. MRC 7361 recorded significantly higher seed cotton yield (3121.6 kg/ha) as compared to Bioseed 6488 (2649.5 kg/ha) and RCH 134 (2107.4 kg/ha). Higher leaf area index (6.18) coupled with better photo synthetically active radiation interception (84.5%) in case of MRC 7361 primarily helped for significantly higher seed cotton yield (SCY). Plant geometries could not affect the yield and PARI (%) significantly. Among nutrient levels, application of 150 per cent Rd fertilizer produced significantly higher seed cotton yield (2825.9 kg/ha) than 100 per cent Rd fertilizer (2374.9 kg/ha) and 125 per cent Rd fertilizer (2677.6 kg/ha).

Key words : *Bt* cotton, Leaf Area Index (LAI), Photosynthetically Active Radiation Interception (PARI)

Bt cotton hybrids have become popular among farmers. Apart from improvement in yield, *Bt* hybrids have also lowered the pest incidence and reduced environmental pollution. Among different agronomic manipulations, selection of potential genotypes having high yield contributing characters, optimum plant stand and suitable fertilization plays crucial role in increasing the productivity of cotton Fulfilment of nutritional requirements of the crop is not only essential for achieving the higher yields but also for fibre quality parameters (Kalaichelvi, 2009). On the contrary, excess application of fertilizers, particularly nitrogen results in increased vegetative growth. Therefore, the present studies were undertaken to identify high yielding *Bt* cotton hybrids and also work out their agronomic requirements under the site specific agro climatic conditions of Faridkot.

MATERIALS AND METHODS

The field experiments were conducted during the *kharif,* 2010 and 2011 at Research Farm of Punjab Agricultural University, Regional Research Station, Faridkot ($30^0$40'N and $74^0$44'E), a typical representative of south western zone (Zone IV) in Punjab. The soil of the experimental field was loamy in texture, slightly alkaline (pH 8.7), normal EC (0.40 m mhos/cm), medium in OC (0.48%), low in available P (7.5 Kg/ha) but high in available K (750 Kg/ha). The Split plot designed experiment replicated thrice comprised of three *Bt* hybrids (*i.e.* MRC 7361,Bioseed 6488 and RCH 134) in main plot, two plant geometries (i.e. 67.5 x 75 and 67.5 x 90 cm) in sub and three nutrient levels (*i.e.* 100% of recommended, 150kg N, 30kg P/ha), (125% of recommended, 187.5kg N, 37.5kg P/ha) and (150% of recommended, 225 kg N, 45kg P/ha) in sub sub plots. The crop was sown in first fortnight of May by dibbling 3-4 seeds/hill which were later thinned to one seedling/hill. Full dose of phosphorus was applied before sowing while nitrogen dose was given in two splits *i.e.* first half at the time of thinning and remaining half at flowering stage. The rain received during the crop season was 432.8mm and 606.4mm for 2010 and 2011, respectively. Digital plant canopy imager was used for leaf area index and photosynthetically active radiation interception (PARI %) at 100 days after sowing. The data were used for calculating PARI by crop as under.

$$PARI\ (\%) = \frac{\text{PAR above the crop canopy - PAR at soil surface}}{\text{PAR above the crop canopy}} \times 100$$

The data were analyzed statistically as per the standard procedure

RESULTS AND DISCUSSION

Effect of *Bt* cotton hybrids: The tested *Bt* cotton hybrids differed significantly for growth parameters like plant height , leaf area index , photo synthetically active radiation interception (PARI %) as well as for seed cotton yield. The results of the pooled data given in the Table 1 indicated that MRC 7361 exhibited significantly higher values for LAI (6.18) as compared to Bioseed 6488 and least value of 4.62 for RCH 134. MRC 7361 recorded significantly higher seed cotton yield (3121.6 kg/ha) as compared to Bioseed 6488 (2649.5 kg/ha) and RCH 134 (2107.4 kg/ha) due to improved leaf area index and PARI (%) which helped in improving yield contributing characters such as sympods and bolls/plant. Nehra *et al.,* (2006) and Manjunatha *et al.,* (2010) reported significant differences for seed cotton yield among the different *Bt* cotton hybrids particularly due to improved bolls/plant. Singh *et al* (2007) also found significant differences for seed cotton yield among *Bt* cotton hybrids due to difference in bolls and sympods/ plant. In present investigations, MRC 7361 recorded significantly better yield by 17.8 and 48.1 per cent over Bioseed 6488 and RCH 134, respectively owing to improved LAI values which in turn helped in capturing of significantly highest (Table1). PARI varied significantly among all the tested *Bt* hybrids and MRC 7361 exhibited statistically higher (84.5%) while RCH 134 recorded least value (72.2%) for PARI. Due to tall and vigorous growing habit, the biomass production was highest for MRC 7361 as compared to other hybrids. As a result of this, MRC 7361 exhibited significantly higher leaf area index (6.18) than Bioseed 6488 (5.38) and RCH 134 (4.62). All of the above said factors further culminated to give higher seed cotton yield for MRC 7361 than rest of the hybrids. Ginning out turn for MRC 7361 (34.6%) was found to be significantly better than Bioseed 6488 (33.8%) though it was *at par* with RCH 134 (34.5%). Similarly, halo length was found to be statistically higher for MRC 7361 (30.4 mm) was found to be significantly better than Bioseed 6488 (27.1 mm) though it was *at par* with RCH 134 (27.4 mm).Pooled data further indicated significantly highest lint yield for MRC 7361 (1080.9) followed by Bioseed 6488 (897.9 kg/ha) and least lint yield under RCH 134 (728.7 kg/ha) .Seed yield was also significantly superior in MRC 7361(2040.6 kg/ha) than Bioseed 6488 and RCH 134 (Table 2).

Effect of plant geometries: The data given in Table 1 revealed that plant geometries could not affect the PARI (%) and seed cotton yield significantly. Srinivasulu *et al.,* (2006) and Brar *et al.,* (2008) also reported non significant differences for seed cotton yield with respect to plant geometries. However in present investigations, pooled data indicated reduced plant height under wider geometry *i. e.* 67.5 x 90 cm, than narrow geometry (67.7 x 75cm). Narayana *et al.,* (2007) reported that bolls/plant was significantly better under wider plant geometry of 120 x 60cm than the closer geometry (90 x60 and 90 x 90cm). Reddy and Gopinath (2008) also observed significantly higher bolls/plant with wider plant geometry (90 x 90cm) as compared to closer one (90 x 60 and 90 x 30cm). Pooled data further revealed significantly better halo length of 29.0 mm in wider geometry (67.5 x 90 cm) as compared to 67.5 x 75 cm (Table 3). However, non significant differences were observed for LAI, GOT, lint and seed yield.

Effect of nutrient levels: There was a significant increase in plant height with each increase in nutrient level. As a result of this statistically highe LAI value of 5.74 was exhibited with 225 kg N and 45kg P/ha (150% RD) as compared to 150kg N, 30kg P/ha (100% RD) levels and (125 % Rd) level (Table 1). Pooled studies further revealed that statistically improved LAI indices (5.74) coupled with significantly highest PARI (85%) with 225 kg N and 45kg P/ha (150% RD) as compared to 150kg N, 30kg P/ha (100% RD) levels have reflected its positive effect on seed cotton yield. Highest level of fertilizer *i. e.* (150% RD, 225 kg N, 45kg P/ha) produced 18.9 and 5.53 per cent higher seed cotton yield (2825.9 kg/ha) than (100 % RD, 2374.9 kg/ha) and 125% RD, 2677.6 kg/ha), respectively (Table 2). PARI improved significantly from 71.6 per cent (150kg N, 30kg P/ha) to 77.3% (187.5kg N, 37.5kg P/ha) and 85.0% (225kg N, 45kg P/ha) for every successive increase in nutrient level. Singh and Rathore (2007) also reported significant improvement in seed cotton yield with increased

Table 1. Effect of different plant geometry and nutritional levels on growth parameters of *Bt* cotton hybrids

Treatments	Plant height at maturity (cm)			LAI			PARI (%)			Seed cotton yield (kg/ha)		
	2010	2011	**Pooled**	2010	2011	**Pooled**	2010	2011	**Pooled**	2010	2011	**Pooled**
***Bt* cotton hybrids**												
Bioseed 6488	121.5	195.9	**158.7**	4.97	5.78	**5.38**	73.0	81.5	**77.2**	2217.5	3081.4	**2649.5**
RCH 134	107.0	169.7	**138.3**	3.80	5.44	**4.62**	64.9	79.5	**72.2**	1897.1	2317.6	**2107.4**
MRC 7361	147.2	205.2	**176.2**	5.91	6.45	**6.18**	78.7	90.3	**84.5**	2795.4	3447.8	**3121.6**
p=0.05	8.1	18.6	**8.4**	0.42	0.65	**0.32**	5.6	5.7	**3.3**	257.1	289.8	**160.9**
Plant geometry												
67.5 x 75 cm	127.4	191.7	**159.5**	5.05	5.81	**5.43**	72.3	82.9	**77.6**	2218.7	2916.9	**2567.8**
67.5 x 90 cm	123.1	188.8	**155.9**	4.74	5.97	**5.36**	72.1	84.7	**78.4**	2387.9	2981.0	**2684.5**
p=0.05	3.7	NS	**3.3**	NS	NS	**NS**	NS	NS	**NS**	NS	NS	**NS**
Nutrient levels												
(100 %RD) (150kg N, 30kg P/ha)	121.3	185.5	**153.4**	4.42	5.50	**4.96**	65.8	77.4	**71.6**	1914.7	2835.1	**2374.9**
(125 % RD) (187.5kg N, 37.5kg P/ha)	125.1	189.4	**157.2**	5.11	5.86	**5.48**	70.9	83.8	**77.3**	2404.0	2951.2	**2677.6**
(150 % RD) (225 kg N, 45kg P/ha)	129.4	195.8	**162.6**	5.16	6.31	**5.74**	80.0	90.1	**85.0**	2591.3	3060.5	**2825.9**
p=0.05	5.0	NS	**4.9**	0.39	0.43	**0.28**	4.2	7.4	**4.1**	184.9	137.7	**112.2**

Table 2. Effect of different plant geometry and nutritional levels on physical parameters , lint and seed yield of *Bt* cotton hybrids

Treatments	GOT (%)			Halo length (mm)			Lint yield (kg/ha)			Seed yield (kg/ha)		
	2010	2011	**Pooled**	2010	2011	**Pooled**	2010	2011	**Pooled**	2010	2011	**Pooled**
***Bt* Cotton hybrids**												
Bioseed 6488	33.7	33.9	**33.8**	26.4	27.8	**27.1**	748.4	1047.3	**897.9**	1469.0	2034.0	**1751.5**
RCH 134	34.1	34.8	**34.5**	26.6	28.3	**27.4**	649.7	807.7	**728.7**	1247.3	1509.9	**1378.6**
MRC 7361	35.0	34.3	**34.6**	30.3	30.5	**30.4**	978.4	1183.5	**1080.9**	1816.9	2264.3	**2040.6**
p=0.05	0.6	0.6	**0.4**	0.7	1.2	**0.6**	97.3	105.1	**59.4**	162.6	185.6	**102.5**
Plant geometry												
67.5 x 75 cm	34.2	34.2	**34.2**	27.3	28.0	**27.6**	761.1	998.2	**879.6**	1457.6	1918.7	**1688.1**
67.5 x 90 cm	34.4	34.5	**34.4**	28.2	29.8	**29.0**	823.3	1027.5	**925.4**	1564.6	1953.5	**1759.1**
p=0.05	NS	NS	**NS**	0.8	0.8	**0.5**	NS	NS	**NS**	NS	NS	**NS**
Nutrient levels												
100 %RD (150kg N, 30kg P/ha)	34.3	34.3	**34.3**	28.1	28.1	**28.1**	660.7	974.1	**817.4**	1253.9	1861.0	**1557.5**
125 % RD (187.5kg N, 37.5kg P/ha)	34.3	34.4	**34.4**	27.2	29.1	**28.2**	828.7	1014.6	**921.6**	1575.3	1936.6	**1756.0**
150 % RD (225 Kg N, 45kg P/ha)	34.2	34.4	**34.3**	27.9	29.5	**28.7**	887.2	1049.8	**968.5**	1704.0	2010.7	**1857.3**
p=0.05	NS	NS	**NS**	0.3	0.7	**0.4**	61.4	52.9	**39.4**	124.8	88.8	**74.5**

N level. Higher seed cotton yield due to more number of bolls per plant under elevated levels of nitrogen has also been reported by Sunitha *et al* (2010) and Bhalerao *et al.,* (2010). Halo length, lint and seed yield under highest nutrition level (150 % Rd) was significantly better than (100 % RD) as well as (125% RD) level of nutrients (Table 2). These results are in conformity with the findings of Biradar *et al.,* (2010) and Srinivashulu *et al.,* (2006).

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Growth, yield and quality of *Bt* cotton under varied plant geometry and nutrient management in rainfed vertisols

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ABSTRACT : The field experiment was conducted at Regional Agricultural Research Station, Lam, Guntur during 2008 to 2010 to compare the performance of *Bt* cotton with its non *Bt* version under varied spacings and fertilizer levels in vertisols and to work out the economics. Seed cotton yield was significantly superior with an increase of 21.7 per cent under closer spacing (90 cm x 45 cm) as compared to wider spacing (120cm x 60cm). Application of fertilizers, over and above recommended dose of fertilizers (120-60-60 NPK kg/ha) had significant difference on seed cotton yield. 150-75-75 NPK kg/ha recorded significantly superior seed cotton yield and was *on par* with 180-90-90 NPK kg/ha.

Key words : *Bt* cotton, NPK levels, plant density.

Cotton crop, the "King of Fibers" popularly known as "White Gold" is the premier commercial crop grown in Andhra Pradesh. With the introduction of *Bt* cotton hybrids, there has been a significant change in the cotton cultivation scenario of India. In Andhra Pradesh, in vertisol under rainfed conditions, *Bt* cotton occupies more than 98 per cent of cotton area. The average production is very low when compared to world's average and is mainly because 70 per cent of cotton is cultivated as rainfed. Cotton producers are currently faced with rising production costs and static or declining return for their commodity (Jost and Cothren, 2000). The *Bt* cotton cultivation resulted into early setting of bolls, which ultimately demanding for more nutrients, further the plant type is having such a canopy architecture, which can adjust well even under close spacing, unlike hybrids. Thus, higher population of these plants could be accommodated in an area by adopting closer spacing because of altered morphoframe following the incorporation of *Bt* gene. Under these circumstances, the best alternative for improved yield net returns from the *Bt* cotton is altering the cultural practices. Vishwanath (2007) recorded significantly higher seed cotton yield with 150 per cent RDF (2420 kg/ha) as compared to control (2139 kg/ha). Hence, with these ideas in view a comparative study of *Bt* and non *Bt* (Non *Bt*) of the same cultivar for optimization of nutrient requirement and crop geometry for achieving higher production and productivity was undertaken in rainfed vertisol.

MATERIALS AND METHODS

The field experiment was conducted during *kharif,* 2008 to 2010 under rainfed condition at Regional Agricultural Research Station, Lam, Guntur. The soil of the experimental site was clay loam in texture, slightly alkaline with pH 7.8, low in available organic carbon (0.38 %), low available nitrogen (188 kg/ha), medium in available phosphorus (28 kg/ha) and high in available potassium (856 kg/ha). A total rainfall of 844.8 mm, 583.9 mm and 1351.7 mm was received in 43, 31 and 65 rainy days, respectively during the period under study as against the decennial average of 893.48 mm in 48 rainy days.The trial was laid out in split split plot design with three replications. The treatments consisted of two cotton hybrids *i.e.,* NCS 145 *Bt* (V_1) and NCS 145 non *Bt* (Non*Bt*) (V_2), two spacings 120 x 60 cm (S_1) and 90 x 45 cm (S_2) and three nutrition levels 120–60 –60 kg NPK/ha (N_1),150-75-75 kg NPK/ha (N_2) and 180-90- 90 NPK ha^{-1} (N_3). Sowing was done by dibbling one seed/hill. Gap filling was done 15 days after sowing. The gross plot size was 7.2 x 5.4 m and the net plot size was 5.2 x 4.2 m. Entire phosphorus was applied in the form of single super phosphate as basal, whereas, nitrogen and potassium were applied in three split doses at 30, 60 and 90 days after sowing as per the treatments in the form of urea and muriate of potash. Necessary plant protection was taken up. Growth and yield parameters like monopodia, sympodia, bolls/plant, boll weight, seed cotton

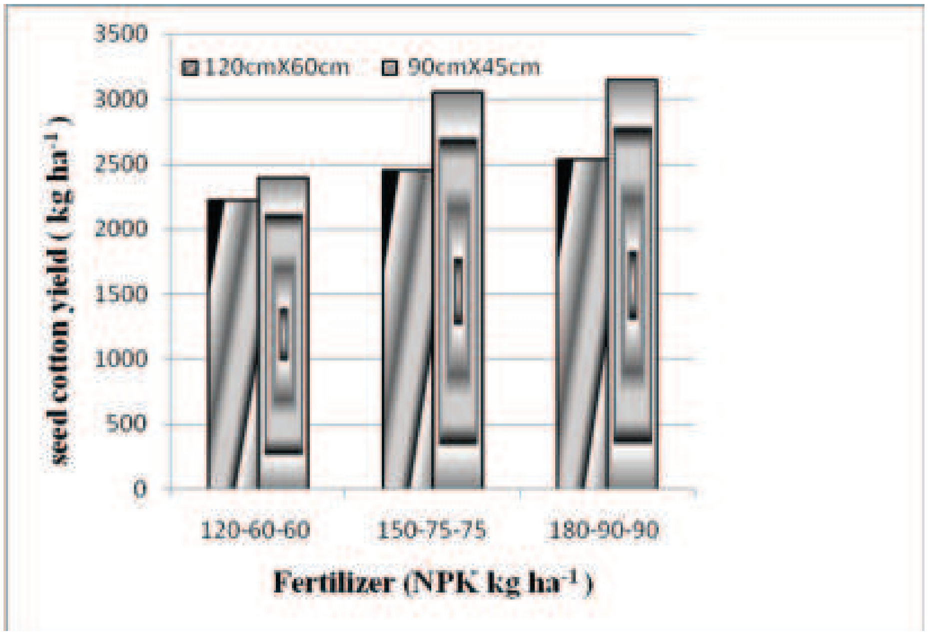

Fig. 1. Seed cotton yield (kg/ha) under varied geometry and fertilizer levels

yield, seed index, lint index, and fibre quality parameters, *viz.*, ginning percent, 2.5 per cent span length, maturity ratio, uniformity ratio, micronaire and fibre strength were recorded. The quality parameters were also analysed. Economics was also calculated on the basis of prevailing market price of inputs and outputs.

RESULTS AND DISCUSSION

The results of the three years study clearly revealed that there was no significant difference in growth , yield contributing characters and seed cotton yield between *Bt* and non *Bt* version of the cotton hybrid NCS 145.

Table 1. Effect of varied spacings and fertilizer levels on *Bt* and non *Bt* cotton. (pooled data 2008 -2010)

Treatments	Plant height (cm)	Monopodia/ plant	Sympodia/ plant	Bolls/ plant	Boll weight (g)	Seed cotton yield (kg/ha)	Net returns (₹)	BCR
Varieties (V)								
V$_1$- NCS 145 *Bt*	112	1.27	19.27	33.64	4.71	2686	57756	2.71
V$_2$ - NCS 145	114	1.36	18.58	32.75	4.71	2600	54776	2.62
SEm +	2	0.75	0.59	1.57	0.07	109		
CD (P=0.05)	NS	0.03	NS	NS	NS	NS		
Spacings (S)								
S$_1$- 120 x 60 cm	117	1.36	19.18	35.69	4.78	2402	48381	2.42
S$_2$- 90 x 45 cm	108	1.09	18.66	29.27	4.64	2924	65506	2.90
SEm +	2	0.06	0.39	1.64	0.07	109		
CD (P=0.05)	6	0.03	0.69	4.82	NS	338		
Fertilizer (F) (kg NPK/ha)								
F$_1$ – 120 - 60 - 60	107	1.10	17.98	28.43	4.54	2304	43865	2.33
F$_2$ – 150 - 75 - 75	114	1.26	19.33	34.77	4.73	2750	59601	2.73
F$_3$ – 180 - 90 - 90	117	1.55	19.85	35.73	4.87	2841	62479	2.78
SEm +	2	0.10	0.57	1.79	0.07	128		
CD (P=0.05)	6	0.24	2.01	6.34	0.23	358		
Interactions	NS	NS	NS	NS	NS	NS		

Regarding spacing, 120 x 60 cm (13,888 plants/ ha) recorded significantly higher growth and yield contributing characters as compared to 90 x 45 cm (24,691 plants/ha) except boll weight. (Table1). The seed cotton yield was increased by 21.7 per cent under closer spacing (90 x 45 cm) as compared to wider spacing. Increasing the plant density/unit land area increased the interplant competition within the plot for natural resources. Due to higher competition between plants, contribution of yield components as bolls per plant was lower at closer spacing (90 x 45 cm) compared to wider spacing (120 x 60 cm). The reduction in yield per plant was compensated through higher plant stand/unit area, accommodating more number of plants under closer spacing (90 x 45 cm) where the plant population has been increased by 78 per cent and recorded the highest BCR (2.90). Similar results were reported by Manjunatha *et al.,* (2010). Application of fertilizers, over and above recommended dose of fertilizers (120-60-60 NPK kg/ha) had significant influence on seed cotton yield. Application of 150-75-75 NPK kg/ha recorded significantly superior seed cotton yield over 120-60-60 NPK kg/ha and was *at par* with 180-90-90 NPK kg/ha (Fig. 1) and the BCR was 2.79 and 2.73, respectively. No significant variations were observed regarding seed index and lint index. None of the physical and quality parameters differed due to spacings and fertilizer levels in *Bt* and its non *Bt* version (Table 2).

Table 2. Quality parameters of *Bt* and non *Bt* cotton under varied spacings and fertilizer levels (pooled data 2008-2010)

Treatments	2.5 per cent span length	Strength	Micronaire	Uniformity ratio	Elongation	Seed index	Lint index	GOT
Varieties (V)								
V_1- NCS 145 *Bt*	30.97	23.80	4.50	48.51	5.73	10.48	5.53	34.43
V_2 - NCS 145	31.29	23.89	4.49	48.43	5.67	10.62	5.58	34.21
SEm +	0.17	0.14	0.04	0.85	0.00	0.17	0.08	0.46
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Spacing (S)								
S_1- 120 x 60 cm	31.16	24.01	4.50	48.59	5.70	10.76	5.62	34.38
S_2- 90 x 45 cm	31.10	23.69	4.50	48.36	5.70	10.35	5.49	34.58
SEm +	0.19	0.19	0.04	0.72	0.02	0.17	0.08	0.46
CD (P=0.05)	NS	NS	NS	NS	NS	0.59	NS	NS
Fertilizer (F) (kg NPK/ha)								
F_1 – 120 - 60 - 60	31.30	23.77	4.48	48.55	5.70	10.37	5.50	34.67
F_2 – 150 - 75 - 75	31.09	23.95	4.52	48.51	5.67	10.44	5.44	34.56
F_3 – 180 - 90 - 90	30.99	23.83	4.47	48.37	5.67	10.83	5.63	34.55
SEm +	0.29	0.28	0.04	0.56	0.03	0.21	0.10	0.59
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Interactions	NS	NS	NS	NS	NS	NS	NS	NS

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Efficacy of *Bt* cotton based double cropping system in black cotton soil under irrigated conditions

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ABSTRACT : The field experiment was conducted during *kharif* and *rabi,* 2007-2008 to 2009-2010 at Cotton Research Station, Junagadh Agricultural University, Junagadh to study the production potential and economics of cotton based double cropping system under irrigated condition. *Bt* cotton - bunch groundnut sequence gave highest seed cotton equivalent yield (5288 kg/ha), maximum land use efficiency of 80.55 per cent and production use efficiency in terms of kg/ha/day (19.68). While higher net monetary returns of Rs. 97897/ha and BCR (2.04) were observed under *Bt* cotton - sesame crop sequence, whereas Rs. 91322/ha and 1.13 in cotton- groundnut sequence, respectively. Production use efficiency in terms of Rs/ha/day (356.2) was noted in *Bt* cotton- fodder sorghum cropping system.

Keywords: *Bt* cotton, double cropping system, land use efficiency

Cotton is the most important non food cash crop, in Gujarat. Area under cotton in Saurashtra region of is about 18 lakh ha and contributes around 65 per cent production in the state. The advent of latest technologies developed by public and private R and D agencies including transgenic *Bt* cotton, which are high yielding, short duration, fertilizer and irrigation responsive and due to satisfactory rainfall in last decade and implementation of rain water harvesting and conservation policies of state government, increased the availability of irrigation water in the region. Therefore, after harvesting of *kharif* *Bt* cotton hybrids, there is scope to grow short duration, less water required, pulses, oil seeds or fodder crops to increase total productivity of the system. Which ultimately enhance resource and land use efficiency and hence, present experiment was planned to identify suitable short duration crop for *Bt* cotton based double cropping system under Saurashtra conditions.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* and *rabi,* 2007-2008 to 2009-2010 at Cotton Research Station, Junagadh Agricultural University, Junagadh. The experiment was laid out in randomized block design with three replications. The soil of the experiment field was clayey with pH of 8.15, low in available nitrogen (231.0 kg/ha), medium in available phosphorus (24.32 kg/ha) and high in available potash (343.5 kg/ha). In *kharif* the base crop *i.e. Bt* cotton was raised under irrigated condition. Seed cotton yield, yield of main and by product of second crop (Table 2) were recorded from each net plot and converted on ha basis. After the harvesting of base crop of *Bt* cotton, various crops were sown as per the treatments (Table 1). The total yield and net returns obtained from individual crop sequences were recorded and subjected to statistical analysis after converting them into cotton equivalent yield as per standard procedures described by Panse and Sukhatme (1967). Land use efficiency (LUE) was calculated on dividing the total duration of crop sequences by 365 and expressed in per cent. Production use efficiency (PUE) values in terms of kg/ha/day was calculated on dividing the production of the sequence by total duration of sequence and production use efficiency (PUE) values in terms of Rs./ha/day were obtained by net return of the sequence divided by total duration of sequence.

RESULTS AND DISCUSSION

Cotton equivalent yield: The three years pooled data presented in Table 2 revealed that the *Bt* cotton followed by bunch groundnut under double cropping system recorded significantly higher seed cotton equivalent yield of 5288 kg/ha, except *Bt* cotton fodder sorghum and *Bt* cotton-okra which recorded seed cotton

Table 1. Recommended package of practices adopted for *Bt* cotton and sequence crops in cotton based cropping system

Crop	Variety	Spacing (cm)	Fertilizer NPK (kg/ha)	Sowing dates			Irrigations		
				2007-2008	2008-2009	2009-2010	2007-2008	2008-2009	2009-2010
Bt Cotton	Paras Brahma *Bt*	120x 45	160-00-00	25/06/2007	22/06/2008	12/06/2009	3	4	5
Wheat	GW 173	22.5	120-60-00	29/12/2007	22/12/2008	17/12/2009	10	8	8
Maize (Fodder)	African tall	22.5	100-50-50	04/01/2008	22/12/2008	02/02/2010	8	8	9
Sorghum (Fodder)	GJ 8	22.5	100-50-50	19/02/2008	02/02/2009	04/03/2010	8	8	7
Groundnut (Bunch)	GG 6	30	25-50-00	04/02/2008	02/02/2009	02/02/2010	6	6	9
Sesame	Gujarat Til 2	30	30-30-00	19/02/2008	02/02/2009	04/03/2010	8	8	10
Okra	GO 2	45	100-50-50	19/02/2008	02/02/2009	04/03/2010	10	7	10
Green gram	GM 4	30	30-30-00	19/02/2008	02/02/2009	04/03/2010	6	5	5
Onion	GWO 1	10	75-60-50	07/01/2008	06/01/2009	17/12/2009	10	10	10

equivalent yield of 4298 and 4459 kg/ha, respectively.

Land use efficiency: Pooled results in Table 2 indicated that *Bt* cotton bunch groundnut recorded maximum land use efficiency of 80.55 per cent followed by cotton onion with 79.27 per cent. Whereas the lowest land use efficiency of 68.00 per cent was recorded under *Bt* cotton fodder maize cropping system as the maize was grown for fodder purpose and harvested the crop just at 45 DAS. Therefore, the land use efficiency differed by virtue of the duration of the crop that was taken after cotton. The results conforms the findings of Narayana *et al.,* (2009) and reported that maximum land use efficiency was observed in *Bt* cotton chilly because in these system crop occupied land for longer duration. Similar results were also found by Kumpawat (2001).

Production use efficiency: The highest production use efficiency in terms of kg/ha/day was recorded in *Bt* cotton bunch groundnut (19.68) and was closely followed by *Bt* cotton sorghum fodder (18.91). Whereas production use efficiency in terms of Rs/ha/day was maximum in *Bt* cotton sorghum fodder (356.2) followed by *Bt* cotton sesame (350.7) and were *at par* with each other. This might be due to high yield of sorghum fodder in short period of time and higher market price of sesame resulted in higher production use efficiency in terms of rupees/ha/day, when compared with maize. Narayana *et al.,* (2009) also reported higher production use efficiency in terms of Rs./ha/day in cotton cucumber crop sequence.

Economics: Three year pooled results given in Table 2 showed that *Bt* cotton sesame recorded significantly highest net return of Rs 97897/ha due to higher selling price of sesame (Table 2), except *Bt* cotton-bunch groundnut, *Bt*

Table 2. Cotton equivalent yield, net return, BCR, land use efficiency and production use efficiency of *Bt* cotton based double cropping system (Three years pooled)

Cropping sequence	Cotton equivalent yield(kg/ha)	Net return (Rs/ha)	BCR	Land use efficiency (%)	Production use efficiency	
					(kg/ha/day)	(Rs/ha/day)
Cotton Wheat	3901	51488	0.78	73.13	14.92	191.5
Cotton Maize	4114	76752	1.65	68.00	17.29	313.8
Cotton Sorghum	4298	90090	1.85	70.49	18.91	356.2
Cotton Groundnut	5288	91322	1.13	80.55	19.68	307.6
Cotton Sesame	4102	97897	2.04	76.69	17.78	350.7
Cotton Okra	4459	71781	0.91	76.20	18.64	260.4
Cotton Green gram	3300	51252	1.11	73.32	12.97	200.8
Cotton Onion	4045	39978	0.42	79.27	16.04	140.0
C.D. (P= 0.05)	1007	25220	0.37		3.48	94.2
CV (%)	9.54	16.0	15.2		8.21	15.3

cotton fodder sorghum and *Bt* cotton fodder maize among the crop sequences. Similar results were also obtained by Narayana *et al.,* (2009). The significantly maximum benefit cost ratio of 2.04 was obtained with *Bt* cotton sesame crop sequence which remained at par *Bt* cotton fodder sorghum cropping system. The higher BCR in *Bt* cotton sesame and *Bt* cotton fodder sorghum crop sequences might be due to short duration of sesame and sorghum fodder and resulted higher selling price that prevailed during the summer for fodder purpose of sorghum and sesame.

Therefore, it can be concluded that *Bt* cotton followed by a field crop like sesame, bunch groundnut, sorghum fodder or maize appeared to be best double cropping systems under calcareous soils of saurashtra region. Where, cotton and subsequent crops were raised under irrigated condition to enhance the land use efficiency with higher production use efficiency of the systems as a whole for achieving higher returns.

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Yield enhancement in cotton with foliar nutrition and FYM under rainfed situations of Andhra Pradesh

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ABSTRACT : A field experiment was conducted at Regional Agricultural Research Station, Lam, Guntur, during *kharif,* 2010-2011 and 2011-2012 to assess the yield enhancement in cotton with soil incorporation of FYM and foliar application of different primary, secondary and micronutrients. The experimental results indicated that significantly higher seed cotton yield (2424kg/ha) was obtained in T_7 *i.e.* recommended dose of fertilizer with FYM and 2 foliar sprays of urea (2%) and DAP (2%) alternatively at 8 days interval from 60DAS onwards followed by T_8 (2424 kg/ha) *i.e.* recommended dose of fertilizer with 2 sprays of KNO_3 (0.5%) at 75 & 90 DAS (2309 kg/ha). All the treatments showed better performance compared to control plot. No significant differences were noticed in fibre quality characters through different treatments imposed in the present study.

Key Words : Cotton, FYM, foliar nutrients

Cotton is the most important crop in coastal region of Andhra Pradesh. Most of the cotton is cultivated under rainfed conditions. Cotton is grown in an area of 18.54 lakh ha producing 48.1 lakh bales with a productivity of 499 kg/ha (Anonymus, 2012). The unavailability of nutrients at critical growth stages is the major cause for lower productivity of cotton. The prevailing energy crisis and hiking fertilizer prices have further warranted a need for judicious use of fertilizers by adoption of improved technologies to ameliorate the deficiencies. To save the cotton crop from nutrient loss, foliar nutrition with different nutrients at particular intervals and enriching the soil with FYM has a vital place. Unpredictable drought condition is common in everywhere. Applying foliar fertilizers after relief of drought stress to stimulate recovery and enhance growth may be beneficial. The advantages of using foliar feeding of plants are quick plant response, small quantity of the nutrient, compensation for the lack of soil fixation, avoiding root uptake problems, increased yield and fiber quality in cotton .

Organic manures like FYM can be effectively used for correcting micronutrients' deficiencies in crops (Rathore *et al.*,1995). Protecting the soil environment by less use of inorganic fertilizers and depend on ecofriendly management measures like organic fertilizers ensures sustainable crop production in the long run. The present study was undertaken to see the effect of different foliar nutrients at particular intervals with and without the use of FYM.

MATERIALS AND METHODS

A field experiment was conducted in black cotton soils under rainfed condition during 2010-2011 and 2011-2012 at Regional Agricultural Research Station, Lam, Guntur.The soil of the experimental site was clayey having p^H 7.84, EC: 0.22 dS/min, low in organic carbon (0.59%), low in available N (195 kg/ha), and medium in available P (18.0 kg/ha) and high in available K (290kg/ha). A randomized block design with 12 treatments replicated thrice with a net plot area of 4.8 x 6m^2. The variety used was RCH 2 *Bt*.The treatments are as follows. T_1 - Control (No fertilizer), T_2 - RDF based on soil test values, T_3 - T_2 + FYM @10t/ha , T_4 - T_2 + 1 foliar spray of urea (2%) at 60 DAS followed by 1 spray of DAP (2%) after 8 days, T_{5-} T_2 + 2 foliar sprays of urea (2%) and DAP (2%) alternatively at 8 days interval from 60 DAS, T_{6-} T_3 + 1 foliar spray of urea (2%) at 60 DAS followed by 1 spray of DAP (2%) after 8 days, T_{7-} T_3 + 2 foliar sprays of urea (2%) and DAP (2%)alternatively at 8 days interval from 60 DAS, T_8 - T_2 + 2 sprays of KNO_3 (0.5%), T_{9-} T_2 + 2 sprays of $MgSO_4$ (0.5%) at 75 and 90 DAS, T_{10} - T_2 + urea (1%) + $ZnSO_4$ (0.5%) at 75 DAS, T_{11-} T_2 + Foliar application of sodium benzoate @ 100 ppm at 75 DAS, T_{12-} T_2 + Foliar application of sodium benzoate @ 100 ppm at 90 DAS. Foliar sprays were given at specified intervals. Data were recorded at 90, 120 DAS and at harvest. Fibre analysis was done to see the effect of foliar spray on cotton. Five plants at random were selected in each plot and sympodia and bolls/ plant, boll weight and seed cotton yield/plant were recorded. The mean data of five plants were subjected to statistical analysis by adopting the standard procedures described by Panse and Suhkatme (1985).

RESULTS AND DISCUSSION

At 90 days after sowing, no significant influence was noticed on plant height and monopodia/plant due to different treatments imposed. The sympodia and bolls/plant were significantly higher in all the treatments compared to control. At 120 days after sowing, significant differences were noticed in sympodia, bolls/plant and dry matter production was significantly high in all the treatments imposed. There was significant improvement in sympodia, bolls and total dry matter production was noticed with T_4, T_5, T_6 and T_7 when compared to control. The FYM incorporated plots T_3, T_6, T_7 had shown better performance in sympodia and other growth parameters compared to the rest of the treatments and this may be due to initial micronutrient supply through FYM and the supplemental foliar nutrition through $MgSO_4$ and $ZnSO_4$ was nullified by the soil incorporated FYM.

Table 1. Studies on yield enhancement in cotton with foliar nutrition and FYM

Treatments	Plant height(cm)		Monopodia/ plant	Sympodia/ plant		Bolls/plant	
	90DAS	120DAS		90DAS	120DAS	90DAS	120DAS
T_1 Control (No fertilizer	85.6	86.4	1.5	11.4	13.9	18.16	19.0
T_2 RDF based on soil test values	87.0	89.2	2.4	13.63	15.4	18.86	30.3
T_3 RDF based on soil test values + 10t/ha of FYM	76.1	86.1	1.9	15.4	17.2	26.32	32.0
T_4 RDF based on soil test values + 1 foliar spray of urea (2%) at 60 DAS followed by 1 spray of DAP (2%) after 8 days	88.4	90.0	2.5	13.63	19.3	21.86	34.3
T_5 RDF based on soil test values + 2 foliar sprays of urea (2%) and DAP (2%) alternatively at 8 days interval from 60 DAS	95.0	100.53	3.5	15.27	17.9	27.06	35.0
T_6 RDF based on soil test values + 10t/ha of FYM + 1 foliar spray of urea (2%) at 60 DAS followed by 1 spray of DAP (2%) after 8 days	87.0	93.8	2.3	15.53	18.9	31.2	33.3
T_7 RDF based on soil test values + 10t/ha of FYM + 2 foliar sprays of urea (2%) and DAP) alternatively at 8 days interval from 60DAS	87.8	97.0	2.3	16.3	21.2	31.6	48.0
T_8 RDF based on soil test values + 2 sprays of KNO3 (0.5%) at 75 and 90 DAS	78.5	87.7	1.8	13.7	15.7	25.86	40.3
T_9 RDF based on soil test values + 2 sprays of MgSO4 (0.5%) at 75 and 90 DAS	91.7	92.9	2.5	14.63	17.1	30.73	40.3
T_{10} RDF based on soil test values + urea (1%) + ZnSO4 (0.5%) at 75 DAS	94.2	96.0	2.6	14.73	17.9	25.63	38.0
T_{11} RDF based on soil test values + Foliar application of sodium benzoate (100 ppm) at 75 DAS	98.6	98.0	2.0	15.63	16.4	18.96	34.1
T_{12} RDF based on soil test values + Foliar application of sodium benzoate (100 ppm) at 90 DAS	94.1	102.5	1.9	14.97	16.2	28.5	28.1
SEm +	8.284	8.02	0.47	0.794	1.19	1.811	1.982
CD (P= 0.05)	NS	NS	NS	2.328	3.51	5.312	5.812
CV (%)	16.0	15.2	57.3	9.5	12.0	9.0	10.0

Table 2. Studies on yield enhancement in cotton with foliar nutrients and FYM on yield and yield components

Treatments (g/Plant)	SCY cotton yield (kg/ha)	Seed weight (g)	Boll matter (kg/ha)	Dry index	Lint index	Seed (%)	GOT
T_1 Control (No fertilizer	57	1031	2.63	2545	3.90	7.86	34
T_2 RDF based on soil test values	99	1427	3.51	3089	5.61	8.92	38
T_3 RDF based on soil test values + 10t/ha of FYM	112	1710	3.86	3536	5.85	10.00	35
T_4 RDF based on soil test values + 1 foliar spray of urea (2%) at 60 DAS followed by 1 spray of DAP (2%) after 8 days	110	1763	3.59	3748	4.43	9.77	32
T_5 RDF based on soil test values + 2 foliar sprays of urea (2%) and DAP (2%) alternatively at 8 days interval from 60 DAS	128	2071	3.86	3866	5.13	9.82	35
T_6 RDF based on soil test values + 10t/ha of FYM + 1 foliar spray of urea (2%) at 60 DAS followed by 1 spray of DAP (2%) after 8 days	141	2159	3.75	4065.3	4.91	9.51	33
T_7 RDF based on soil test values + 10t/ha of FYM + 2 foliar sprays of urea (2%) and DAP alternatively at 8 days interval from 60DAS	153	2424	3.96	4065	4.56	8.75	36
T_8 RDF based on soil test values + 2 sprays of KNO3 (0.5%) at 75 and 90 DAS	108	2309	3.63	3289.3	5.08	9.88	34
T_9 RDF based on soil test values + 2 sprays of MgSO4 (0.5%) at 75 and 90 DAS	142	1921	3.643	3428	4.87	9.36	33
T_{10} RDF based on soil test values + urea (1%) + ZnSO4 (0.5%) at 75 DAS	143	1812	3.77	3908	4.93	10.24	32
T_{11} RDF based on soil test values + foliar application of sodium benzoate (100 ppm) at 75 DAS	112	1431	3.49	3054	5.25	7.86	38
T_{12} RDF based on soil test values + foliar application of sodium benzoate (100 ppm) at 90 DAS	91	1445	3.57	2998	4.89	8.23	37
SEm +	6.67	251.4	0.19	183.64	0.28	0.326	1.36
CD (P= 0.05)	19.58	737.5	0.57	538.57	0.83	0.956	4.00
CV (%)	9.9	24.1	9.4	9.5	9.9	6.1	6.8

Similar findings were reported by Blase *et al.*, (2006) in cotton.

All the treatments except T_{11} and T_{12} had shown improved seed cotton yield when compared to control in black cotton soils under rainfed conditions. The higher seed cotton yield due to these treatments was associated with higher number of sympodia and boll number per plant coupled with higher dry matter production and boll weight. Significantly higher seed cotton yield was recorded with T_{7-} RDF based on soil test values + FYM @10t/ha + 2 foliar sprays of urea (2%) and DAP (2%) alternatively at 8 days interval from 60DAS (2424kg/ha) followed by T_{8} - RDF based on soil test values + 2 sprays of KNO3 (0.5%) (2309kg/ha), T_{6} - RDF based on soil test values + FYM @10t/ha + 1 foliar spray of urea (2%) at 60 DAS followed by 1 spray of DAP (2%) after 8 days (2159kg/ha) and T_{5-} RDF based on soil test values + 2 foliar sprays of urea (2%) and DAP (2%) alternatively at 8 days interval from 60DAS (2071kg/ha). The treatments T_{9-} T_2 + 2 sprays of $MgSO_4$ (0.5%) at 75 and 90 DAS, T_{10} - T_2 + urea (1 %) + $ZnSO_4$ (0.5%) at 75 DAS had shown significantly higher seed cotton yield compared to control and it was on par with T_3 - RDF based on soil test values + FYM @10t/ha. The foliar nutrition did not show any impact on fibre quality of cotton.

As per the findings of Duli Zhao and Derrick (2003) and (Rosolem *et al.*, 2000) the increased yield in rice and wheat with foliar nutrition is due to increased photosynthetic rate and better translocation of photosynthates from source to sink. The results of this experiment are in accordance with the findings of the above authors and the foliar nutrition of urea (2%) and DAP alternately at 8 days interval from 60 days after sowing helped the plants to survive during nutrient starvation at peak growing stages, thereby increased yields.

Hence, it can be concluded that seed cotton yield in Bt cotton can be improved under rainfed conditions in black cotton soils with the incorporation of 10 t FYM/ha coupled with soil test based recommended N, P, K fertilizers and need based supply of nutrients through foliar application.

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Influence of weather parameters on growth and yield of *Bt* cotton under Krishna agro climatic zone of Andhra Pradesh

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ABSTRACT : A field experiment was conducted on clay soils of Regional Agricultural Research Station, Guntur during *kharif,* 2010-2011 and 2011-2012 to know the influence of weather parameters on growth and yield of *kharif Bt* cotton grown under varying dates of sowings in Krishna agro climatic zone of Andhra Pradesh. Results indicated that the maximum rainfall (534,4 mm) received by crop sown on 2nd July and lowest received crop sown on 1st of October. Due to variation in dates of sowings, plant height, monopodia and sympodia, bolls/plant, boll weight, dry matter production and yield were affected greatly. Average plant height (91 cm), monopodia (2) and sympodia (19) bolls/plant (44), boll weight (44g/10 bolls), dry matter production (783 g.m2) and yield (2510 kg) was highest in crop sown on 2nd July and was lowest in crop sown on 1st of October, respectively. Correlation coefficient between growth, yield and its components and agrometeorological parameters were calculated and parameters showing statistically significant correlation. Rainfall, mean maximum and minimum temperature and RH2 has significantly positive correlation on yield and yield parameters except at monopodial stage but sunshine h, GDD and HTU increased with delay in sowings and has shown negative correlation.

Key words : Agro climatic environment, *Bt* cotton, correlation coefficient, heliothermal units

Cotton is an important commercial crop and a widely traded commodity across the world. Its yield is sensitive to weather, soil as well as management practices. The unreliability and delay in the rainfall is posing serious problem in cotton yield. In the present investigation efforts were made to assess the performance of *Bt* cotton hybrid in relation to climate and yield under delayed sowings. Response of *Bt* cotton to dates of sowing indicated that yield reduction to the extent of 18.8 and 54.9 per cent was noticed when sowing was delayed from June to July and further to August, respectively (Hallikeri and Halemani, 2008)

In Andhra Pradesh, cotton cultivated under dry and irrigated farming system. Area under cotton in these areas reduced to greater extent due to late sowings caused by late arrival of monsoon and late release of canal water. Performance of *Bt* cotton hybrid under such late sown conditions needs to be assessed. Therefore, it is needed to study the response of *Bt* cotton hybrid under delayed planting under different dates of sowings. Information on delayed sowing of *Bt* cotton hybrid will be very much useful under monsoon vagaries.

MATERIALS AND METHODS

Field experiment was conducted at Regional Agricultural Research Station, Guntur (Latitude: $16^{0}18^{I}$ Longitude: $80^{0}29^{I}$ Altitude: 33 m. a. m. s. l) verticals. The climate is subtropical with mean annual rainfall of 950 mm. The soil of the experiment field was clay loam in texture, neutral to slightly alkaline in reaction (pH 7.8 to 8.2), medium in organic carbon content (0.51%), low in available N (220 kg/ha), high in available P (58.7 kg/ha) and available K (1099 kg/ha). The experiment was conducted during *kharif,* 2010-2011 and 2011-2012 in Krishna agroclimatic zone. The experimental treatments consists of six dates of sowing *viz.*, 2nd July, 1st August, 2nd August, 1st September 2nd September. 1st October and 2nd October in split plot design with three replications. The most dominant *Bt* NCS 145 (Bunny) was grown. Daily agro meteorological data from AMFU of RARS, Lam was collected. The agro meteorological indices such as growing degree day (GDD) and heliothermal units (HTU) which are the derived parameters of temperatures, sunshine h have been estimated. Base temperature considered for growth for this study was 15.5^{0}C (Rishi *et al.,* 2007). Phenophasewise mean values of maximum and minimum temperatures, sunshine h (SSH), morning relative humidity (RHI), after relative humidity (RHII), rainfall growing degree day (GDD) heliothermal unit (HTU) was calculated and correlated with cotton lint yield, dry matter accumulation, 10 boll weight, bolls, monopodia/ plant and sympodia/plant and plant height.

RESULTS AND DISCUSSION

Agroclimatic environment : Agroclimatic factors prevailing during different growth have been shown Table 1. Highest rainfall (534.4 mm) was received in 1st date of sowing treatment *i.e.*, 2nd July and lowest was received in last date of sowing *i.e.*, 1st October. Among the growth phages, seedling phase received 45.2 mm, vegetative phase received 176.2 mm, square formation received 205.8 mm, peak flowering 71.8

Table 1. Agroclimatic environment of *kharif* cotton in 2011-2012

Date of sowing	Growth stages	Total rainfall (mm)	Mean temperatures (⁰C) Maximum	Mininmum	SSH (h/d)	RH1 (%)	RH2 (%)	GDD (⁰C)	HTU
D1- 2nd July	**S1-** Seedling (0-9)	45.2	31.2	21.0	3.5	54.9	35.6	26	91
	S2- Vegetable phase (10-35)	176.2	33.9	25.8	4.3	74.7	58.3	31	135
	S3- Square formation (36-59)	205.8	32.4	25.4	2.7	79.8	65.4	30	78
	S4- Peak flowering (60-95)	71.8	35.4	25.0	6.1	76.6	55.8	32	197
	S5- Boll development (96-110)	35.4	32.6	22.0	7.0	76.8	55.2	28	196
	S6- Boll dev. to harvest (111-160)	0.0	32.0	19.8	8.1	82.3	48.7	26	211
	Total phage	**534.4**	**32.9**	**23.2**	**5.3**	**74.2**	**53.2**	**29**	**152**
D2- 1st Aug	**S1-** Seedling (0-9)	30.8	34.2	25.7	5.4	76.8	54.7	31	169
	S2- Vegetable phase (10-35)	233.4	33.5	26.5	2.9	82.5	68.4	31	90
	S3- Square formation (36-59)	44.0	33.3	24.7	4.9	72.0	52.6	226	1109
	S4- Peak flowering (60-95)	62.8	34.3	24.3	5.5	77.0	58.7	31	201
	S5- Boll development (96-110)	0.0	32.4	19.6	7.6	76.6	47.3	186	1411
	S6- Boll dev. to harvest (111-160)	27.4	35.6	24.4	7.2	75.7	57.1	226	1105
	Total phage	**398.4**	**33.9**	**24.2**	**5.6**	**76.8**	**56.5**	**123**	**680**
D3- 2nd Aug	**S1-** Seedling (0-9)	155	30.0	24.9	3.1	86.7	77.4	418	1195
	S2- Vegetable phase (10-35)	88.6	33.2	25.6	3.0	78.4	61.9	432	1182
	S3- Square formation (36-59)	23	35.9	25.0	6.6	73.8	54.2	426	2827
	S4- Peak flowering (60-95)	62.8	32.9	22.0	7.1	78.4	54.5	375	2666
	S5- Boll development (96-110)	0	32.0	20.3	8.9	80.6	48.9	349	3094
	S6- Boll dev. to harvest (111-160)	147.9	30.2	17.7	6.7	89.7	55.7	306	2059
	Total phage	**477.3**	**32.4**	**22.5**	**5.9**	**82.3**	**58.8**	**384**	**2171**
D4- 1st Sept	**S1-** Seedling (0-9)	19.6	33.9	26.4	3.2	72.2	55.9	240	759
	S2- Vegetable phase (10-35)	44.4	33.5	25.2	6.1	74.1	54.0	232	1407
	S3- Square formation (36-59)	62.8	32.6	23.5	6.1	75.6	57.5	216	1305
	S4- Peak flowering (60-95)	0.0	32.4	20.4	7.1	78.8	50.1	191	1355
	S5- Boll development (96-110)	0.0	31.3	18.1	8.6	85.9	46.4	172	1480
	S6- Boll dev. to harvest (111-160)	147.9	30.5	17.9	8.1	90.8	57.8	170	1192
	Total phage	**274.7**	**32.4**	**21.9**	**6.5**	**79.6**	**53.6**	**204**	**1250**
D5- 2nd Sept	**S1-** Seedling (0-9)	23.2	34.8	25.6	5.3	75.8	51.7	234	1143
	S2- Vegetable phase (10-35)	32.8	35.8	24.6	7.2	75.5	55.8	228	1630
	S3- Square formation (36-59)	35.4	32.4	22.0	6.8	77.5	55.4	204	1383
	S4- Peak Flowering (60-95)	0.0	32.0	19.7	8.2	82.2	48.1	185	1522
	S5- Boll development (96-110)	2.4	33.2	24.1	6.2	80.2	59.5	221	1370
	S6- Boll dev. to harvest (111-160)	0.0	32.4	19.5	7.6	76.4	47.1	185	1403
	Total phage	**91.4**	**33.8**	**23.0**	**6.9**	**77.8**	**52.8**	**213**	**1445**
D6- 1st Oct	**S1-** Seedling (0-9)	0.0	36.6	24.8	7.5	69.6	60.9	228	1707
	S2- Vegetable phase (10-35)	62.8	33.2	24.1	6.2	80.2	59.5	221	1370
	S3- Square formation (36-59)	0.0	32.4	19.5	7.6	76.4	47.1	185	1403
	S4- Peak Flowering (60-95)	2.5	31.1	19.1	7.4	85.9	50.4	180	1338
	S5- Boll development (96-110)	4.0	29.8	18.1	7.0	92.5	58.0	171	1203
	S6- Boll dev. to harvest (111-160)	0.0	33.9	18.7	8.2	92.0	49.0	180	1473
	Total phage	**69.3**	**32.8**	**20.7**	**7.3**	**82.8**	**54.2**	**194**	**1416**

mm and boll development received 35.4 mm was received in 2nd July sowing. Among the growth phages, seedling phase received no rain, vegetative phase 62.8 mm, square formation received no rain, peak flowering 2.5 mm, boll development 4 mm and harvest phase received no rain in 1st October sown crop. The amount of rainfall distribution was different among the sowings in different phases and it was decreased with delay in sowings. It is evident that rainfall has greater role on yield realization in log duration crop like cotton. Both mean maximum and minimum temp. were highest during crop sown on 1st FN of August (33.9 ⁰C and 24.2 ⁰C). Sunshine h were increased with delay in sowing, maximum sunshine h (SSH) was received by the crop sown on 1st FN of October.

Growth, yield, yield components and crop weather relation : Due to variation in dates of sowings, plant height, monopodia and sympodia, bolls/plant, boll weight, dry matter production and yield was affected greatly. Average plant height (92.3 cm), monopodia (2.4), sympodia (19), bolls/plant (51), boll weight (44g/10 bolls), dry matter production (783 g.m2) and yield (2510 kg) was highest in crop sowing on 2nd July and was lowest in crop sown on 1st October respectively (Table 2 and 3). The response of *Bt* cotton to dates of sowing indicate that yield reduction to the extent of 27.5 to 99.4 per cent was noticed when sowing was delayed from August to October and these results akin to Hallikeri and Halemani, (2008).

Correlation coefficient between growth, yield and its components and agrometeorologyical parameters were calculated and parameters showing statistically significant correlation. Rainfall, mean maximum and minimum temperature and RHII has significantly positive correlation on all yield and yield parameters except at monopodial stage but sunshine h, GDD and HTU increased with delay in sowings and has sown negative correlation.

Table 2. Effect of dates of sowing on growth, yield and yield parameters of cotton

Dates	Plant height (cm)	Mono-podia/ plant	Sym-podia/ plant	Bolls/ plant	Ten Boll weight (g)	Dry matter (g/m2)	Yield (kg/ha)
D1-2nd July	98.3	2.4	21	51	44	783	2510
D2-1st August	93.7	2.0	19	44	39	703	1820
D3-2nd August	91.3	1.8	18	31	34	583	1450
D4-1st September	80.3	1.3	16	29	25	508	600
D5-2nd September	76.3	1.1	14	10	22	333	130
D6-1st October	48.3	1.0	9	3	10	200	16

Table 3. Correlation coefficients between growth, yield and yield attributes and agro meteorological parameters

Yield and yield parameter	Total rainfall (mm)	Mean temperatures (⁰C)		SSH (h/d)	RH1 (%)	RH2 (%)	GDD (⁰C)	HTU
		Max	Min					
Cotton lint yield (kg/ha)	0.95	0.01	0.66	-0.98	-0.98	0.31	-0.41	-0.58
Dry matter accumulation (g.m2)	0.89	0.05	0.73	-0.96	-0.96	0.28	-0.38	-0.56
Ten boll weight (g)	0.88	0.22	0.86	-0.96	-0.96	0.28	-0.33	-0.49
Bolls/plant	0.87	0.12	0.77	-0.93	-0.95	0.35	-0.37	-0.54
Monopodia/plant	0.09	-0.11	0.14	-0.14	-0.14	-0.64	-0.39	-0.41
Sympodia/plant	0.76	0.19	0.82	-0.86	-0.86	0.19	-0.35	-0.51
Plant height (cm)	0.65	0.05	0.68	-0.71	-0.72	0.05	-0.25	-0.40

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Impact analysis of *Bt* cotton production technologies on yield and profit of Vidarbha farmers

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ABSTRACT : In Vidarbha region, shallow soils coupled with less knowledge on suitable technologies with respect to required nutrients , intra row spacing and soil moisture conservation are the major limiting factors for cotton production. The impact study was conducted in Nandura and Loni village in Babhulgaon *Taluka*, of Yeotmal district to assess impact of three cotton production technologies comprised of T_1- INM + PI (75x75cm), T_2-INM with 75x75cm, T_3- INM with 75x60 cm (intra row closer spacing) and were compared with farmer's practice (75 x 75cm) The results of mean data on seed cotton yield (q/ha) of bunny *Bt* revealed that adopting T_1- INM+PI (75x75cm), T_2-INM with 75x75cm, T_3- INM with 75x60 cm (intra - row closer spacing) led to mean increase of 60 , 25 and 42 per cent of seed cotton yield respectively as compared to farmers practice (75 x 75 cm). Per ha net profit realized from disposing of seed cotton , cotton stalk chips and following of clean cotton practice from INM + PI technology intervention in *Bt* cotton was found to be significantly highest being of Rs.61,668 closely followed by INM with closer spacing of intra row (75 x 60 cm) of Rs. 53,571 and both were statistically significant over that of farmers' practice Rs.32,570. The base line value for cost of cultivation was Rs. 15,523/ha and net profit was Rs.33,730/ha

Maharashtra state has an estimated cotton area of 4 million ha out of which 97 per cent of area is under rainfed and major share in Vidarbha region. As cotton is a major crop, the farmer's economy of Vidarbha region is closely linked to cotton production. The production of cotton depends on rainfall which directly focuses on farmers' income and livelihood security. Yeotmal district of the Vidarbha had cotton area of 3.79 lakh ha with a production of 1.21 lakh tonnes. Farmers of this district are growing mostly *Bt* cotton hybrids. Out of so many *Bt* hybrids, Bunny *Bt* (BG I or BG II) is more preferred one . The normal annual rainfall is ranged from 950 to 1000 mm, 80-85 per cent of which is received mostly from June to September and later it recedes, when crop warrant more water. (Singh *et al*., 2011). Inconsistent distribution of rainfall coupled with cultivation in existing shallow soils (depth< 50 cm) and non adoption of appropriate technologies affect the cotton production. Shallow soils in addition to less knowledge on suitable technologies with respect to required nutrients , intra row spacing and soil moisture conservation by opening of furrows in between rows of cotton are the major limiting factors for the causes of low productivity of this domain (Pawar and Pawar 2000). The cotton growing soils of Yeotmal comes under the category of Typic Haplusterts (Vertisols) on undulating plains which are shallow to deep in depth and clayey in texture. Simultaneously, the costs incurred and returns realised from cotton farming determine the profit and livelihood security of farmers (Reddy *et al*., 1997). The length of growing period of the regions ranges from 135 to 150 days in shallow soils to 150-160 days in medium deep soils, which have associated effects on *Bt* cotton production.

MATERIALS AND METHODS

Two villages namely, Nandura and Loni (Latitude 20^0 30' Longitude 78^0 15') in Babhulgaon *Taluka*, of Yeotmal district were selected to assess impact and economic analysis of different agronomic technologies in *Bt* cotton (cultivar NCS 145(Bunny)) production system . On farm trials with farmers participatory approach were conducted in total of 60 ac land involving of 30 farmers (mean area of 2 ac for each farmer) of the above said villages. Three cotton production technologies comprised of T_1- Integrated Nutrient Management (INM) + Protective irrigation (planted at 75x75cm), T_2-INM with 75x75cm, T_3- INM with 75x60 cm (intra - row closer spacing) were demonstrated and compared with farmer's practice (75 x 75cm) . The farmers practice consisted of application of nitrogenous fertilisers more than optimum without phosphorus and potassium and bio fertiliser. The INM package consisted of nutrient levels (90:

20:39 kg NPK /ha) + 10 kg $ZnSO_4$ /ha + 1 t FYM/ ha + PSB @ 250g/ha + 2% DAP foliar spray). Each component technology was replicated into the fields of 10 farmers for statistical comparison and in total of 30 farmers were involved. Economic value of cotton stalks chip and price advantage of clean cotton picking were also included , while calculating the returns . Prevailing market price /q of cotton stalk chips was Rs. 500 , which attract labour cost + chipping cost of Rs.300/q, thus ultimately gives a profit of around Rs. 200/q .

RESULTS AND DISCUSSION

Base line survey : Two villages (Nandura and Loni) which is known for predominantly cotton cultivation since many years were selected for the study. Proportionate random sampling technique was used for selection of 60 farmers including 30 farmers for technologies adoption (adopted farmers) and 30 control farmers (non adopted farmers). Data on seed cotton yield, cost of inputs involved, return from produce and by produce and socio economic and biophysical parameters were collected from adopted and non adopted farmers by personal interview and tabulated. The analysis of socio economic profile of farmers from adopted as well non-adopted farmers revealed that majority of them were literate, had an average family size of 4-5 members, and medium to large land holdings(Table 1A). The cropping pattern was dominated by cotton in adopted farms and less area under cotton in non adopted farms. The farmers incurred Rs. 15,523/ha as expenditure towards the cost of cultivation and earned a net profit of Rs.33,730/ha in the year 2007 before the adoption of integrated cotton production technologies (Table 1B) which was considered as base line value

Table 1A. Base line survey before implementation of production technologies

S. No.	Details	Adopted farmers	Control (Non adopted)
i	Farmers selection	30	30
ii	Total area (ha)	112.4	90.8
iii	Area/ farm (ha)	3.7	2.9
iv	Family size (average)	5.1	4.9
v	Literacy (%)	80	82
vi	Crop: Cotton(ha) Other (Sorghum and soybean)	65.846.6	41.258.8

Table 1B. Economic aspect of input use before investigations (2007)

Input used	Base line expenditure (2007)
Human labour	5235
Bullock labour	1510
Seed	3150
Fertilizer	3258
Plant protection cost (Rs.)	870
Others	1500
Total cost	15523
Net income from seed cotton	33730

Seed cotton yield : The results of four years mean data on seed cotton yield (q/ha) of Bunny *Bt* revealed that adopting of T_1- INM + PI (planted at 75x75cm), T_2-INM with 75x75cm, T_3-INM with 75x60 cm (intra row closer spacing) led to mean increase of 60 , 25 and 42 per cent of seed cotton yield, respectively (Table 2) with adopted farmers as compared to non adopted . The similar findings on yield enhancement by technological adoption was reported by Pawar and Pawar, 2006. Among the production technologies, higher mean seed cotton yield (22.24 q/ha) was obtained with the practice of INM + PI (2) (INM + PI) followed by INM with closer intra row spacing (19.70 q/ha) as compared to farmers method (13.87 q/ha). One protective irrigation at initiation of boll formation during 70 to75 days after sowing (DAS) and one irrigation at 50 per cent boll formation stage during 85 to 90 DAS along with INM significantly increased the yield of seed cotton (60%) over farmers practice and 30 per cent increase over a spacing of 75x 75cm with INM. Intra row close spacing (75 x 60cm) had registered higher seed cotton yield (14 %) as compared to normal spacing 75x75 cm with the same nutrient level. It is clear that application of INM with close spacing (intra row spacing of 60 cm) was found to be beneficial for rainfed *Bt* cotton if no irrigation facility is available at farmers' field. Closer spaced (75 x 60 cm) *Bt* cotton crop cover the land area faster by profuse canopy growth than conventionally spaced cotton (75 x 75 cm) , leading to greater light interception and better efficiency in controlling weeds by smothering effect. Application of organic manure @ of 1 t FYM

Table 2. Effect of technologies on yield of *Bt* cotton of adopted *v/s* non adopted farmers

Treatments	Seed cotton yield (q/ha)				**Mean**	Per cent increase over farmer's practice
	2008-2009	2009-2010	2010-2011	2011-2012		
T1 INM+ PI (75x75cm)	16.62	21.82	24.20	26.30	**22.24**	60
T2 INM (75x75cm)	11.65	15.82	22.10	19.35	**17.23**	24
T3 INM (75x60 cm)	13.42	20.76	23.50	21.12	**19.70**	42
T4 Non adopted FP (75x75cm)	10.09	14.88	14.90	15.62	**13.87**	-
SEd±	0.37	0.37	0.69	0.40	**0.45**	-
CD (p=0.05)	0.76	0.76	1.35	0.81	**0.92**	-

/ha in each year under INM practice could also helped in conserving moisture resulting in increased seed cotton yield. Singh *et al.*, 2011 reported that cultivation of cotton with protective irrigation in alternate furrows at boll development stage enhanced productivity and it was nearly double than that of the pure rainfed condition. Significantly higher dry matter of cotton stalks was obtained in the plots of INM+ PI (15.65 q/ha) and INM with closer intra row spacing (75 x 60 cm) (14.52 q/ha) as compared to 75 x 75cm (13.40 q/ha) (Table 3).

Economic returns from seed cotton yield : The economic analysis of *Bt* cotton (Table 3) indicated that the significantly highest/ha gross returns realised from selling of seed cotton of Rs. 79,591 was recorded with INM + PI technology followed by INM with closer intra row spacing (Rs.70,501) as compared to non adopted farmers practice (Rs.49,637). It is clear that the technology of two protective irrigations with INM in *Bt* cotton was found superior over other technologies and farmers practice in terms of economic returns. INM with intra - row closer spacing (75 x 60 cm) had significantly higher gross returns over normal spacing (75x75 cm in farmer's method).

Economic returns from cotton stalk chipping : Value addition of cotton stalk by chipping, enhanced the demand and the demand was more than raw cotton stalks because cotton stalk chips material is readily used in preparation of cardboard, plywood, coke and cotton stalks compost. The economic value of cotton stalks chips was calculated as sole price of cotton chips- total expenditure (labour cost + transportation + hiring cost of chipping machine). Per hectare returns from cotton stalks chips was found in the range of Rs. 2680 to Rs. 3130 , which was additional return to farmers in addition to gross returns obtained from seed cotton yield. The cotton stalks production was in the range from 13.5 to 15.7 q/ha with the intervention of production technologies in adopted farmers fields.

Table 3. Effect of technologies on economic aspects in cotton production (Pooled data)

Production technologies	Seed cotton yield (q/ha)	Cotton stalk yield (q/ha)	Returns from seed cotton (Rs/ha) (A)	Returns from cotton stalks chips (Rs/ha) (B)	Gross returns (Rs/ha) (A+B)	Cost of culti-vation (Rs/ha)	Net returns (Rs/ha)	**Returns due to clean cotton (Rs/ha)	Net profit (Rs/ha)
T1 INM +PI (75x75cm)	22.24	15.65	79591	3130	82721	23277	59444	2224	61668
T2 INM (75x75cm)	17.23	13.40	61662	2680	64342	20331	44011	1723	45734
T3 INM (75x60cm)	19.70	14.52	70501	2904	73405	21804	51601	1970	53571
T4 Non adopted FP(75x75 cm)	13.87	*	49637	-	49637	17067	32570	-	-
SEd±	0.45	0.2	428.83	-	429	298	286	-	290
CD (P=0.05)	0.92	0.4	879.90	-	880	613	588	-	611

* Economic value of cotton stalk of non adopted farmer's field is not taken into income
** Rs100/ql of seed cotton received by the adopted farmers
Price of seed cotton (mean of 4 years) is considered Rs. 3578.73

Similar findings were reported by Pawar and Pawar, 2006. The clean cotton practice followed enhanced the net return with range of Rs1,723 to Rs2, 224/ha with different selected technologies for adoption

Net profit : Per/ha net profit realised from disposing of seed cotton , selling of cotton stalk chips and following of clean cotton practice from INM + PI technology intervention in *Bt* cotton was found to be significantly highest being of Rs.61,668 closely followed by INM with closer spacing of intra row (75 x 60 cm) of Rs. 53,571 and both were statistically significant over that of farmers' practice Rs.32,570. The results are in conformity with the earlier findings of Sarode, (1997) and Singh *et al*., (2011).

From the above investigations it could be inferred that cotton cultivation in Vidharba region with following of INM with protective irrigation was found more profitable. Wherever irrigation is possible this technology may be adopted in other places, INM with closer spacing (78 x 60 cm) is the better options. The study shows that adoption of improved production technologies has made a profitable impact to rainfed farmers. In short given the right kind of support services like technology and extension, the farmers could achieve higher yield and net profit over the conventionally practised methods of cotton production.

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Effect of differential rate application of fertilizers with precision planter on growth and yield of cotton (*Gossypium hirsutum* L.).

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ABSTRACT : An experiment on planting with precision cotton planter for placement of fertilizers at different depths and proportions under reduced tillage conditions was conducted during 2009 and 2010 at Research Farm, Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana.The maximum plant height, dry weight, sympodial branches/plant, yield attributes and yield were recorded with the placement of 70 per cent fertilizers at 10 cm and 30 per cent at 20 cm depths, during both the years. The band placement of fertilizers at two depths (70 % fertilizer at 15 cm + 30 % at 25cm depth; 50 % fertilizer at 15 cm + 50 % at 25cm depth; 70 % fertilizer at 10 cm + 30 % at 20cm depth and 50 % fertilizer at 10 cm + 50 % at 20 cm depth) treatments produced significantly more plant height, dry weight, sympodial branches/ plant, yield attributing and yield as compared to band placement of fertilizers at one depth (100 % fertilizer at 10 cm depth and 100 per cent fertilizer at 15 cm depth) treatments and control (broadcasting of 100 % fertilizers) treatment. The application of 100 per cent fertilizer at 10 or 15 cm depth produced growth parameters (plant height, dry weight and sympodial branches/plant), yield attributes and yield *at par* with control (broadcasting of 100 per cent fertilizers) treatment.

Key words: Cotton, fertilizer, growth, precision planter, seed cotton yield

Cotton (*Gossypium* spp), the king of fibres, is an industrial commodity of world wide importance. It is the most important fibre that meets almost 85 per cent of the total fibre requirement of textile industry of India. Cotton has the slowest early growth and the lowest nutrient uptake initially which increases rapidly afterwards. Approximately the uptake of 76 per cent of total N, 86 per cent of P and 82 per cent of K take place in cotton between 49 to 99 days after planting (Schwab *et al.*, 2000). Approximately, 58 to 71 per cent, 30 to 40 per cent and less than 2 per cent of total cotton growing roots are located in the top 20, 20-40 and below 40 cm soil depth, respectively (Reddy *et al.,* 1997). Moreover broadcasting of fertilizers, especially P and K, produces fixation problems due to more soil contact. Only 20 to 30 per cent of P and K fertilizers are effectively used by crops, while the remaining gets fixed within the soil (Rowse and Stone, 1980). Contrary to this loss, the basal application of fertilizers using planters and seed drills have been found to be effective, but application of fertilizers even by these methods does not distribute fertilizers evenly as/the need of roots. Keeping in view the above facts, a study on the effect of differential rate placement of fertilizers at different depths in cotton was conducted using a precision cotton planter developed by Sharma (2011).

MATERIALS AND METHODS

The field experiments were conducted in well drained sandy loam soil under irrigated condition. The major nutrient status of the soil was low in available N and medium in P and K with pH 7.8. The experiment was laid out in a randomized block design with four replications comprising of seven treatments (T_1=70 % at 15 cm + 30 % at 25 cm depths ; T_2=50% at 15 cm + 50 % at 25 cm depths ; T_3=70 % at 10 cm + 30 % at 20 cm depths ; T_4=50 % of fertilizers at 10 cm+ 50 % at 20 cm depths; T_5=100 % at 10 cm depths ; T_6=100 % at 15 cm depth and T_7=broadcasting of 100 %). The experiments were conducted during *kharif,* 2009 and 2010 at Department of Farm Machinery and Power Engineering, Punjab Agriculture University, Ludhiana. No preparatory tillage was given for six treatments to be sown with precision cotton planter whereas fine seed bed was prepared with a tractor drawn rotavator followed by planking for broadcasting of 100 per cent fertilizer treatment. Cotton hybrid RCH 134 *Bt* was planted with precision cotton planter for six treatments and manually for control (broadcasting of 100 % fertilizers), at spacing of 67.5 x 90 cm. The recommended dose of phosphorus (27 kg/ha) as Diammonium phosphate, potassium (20 kg/ha) as muriate of potash and half nitrogen (65 kg/ha) as urea were applied at planting as per treatments. Top dressing of half dose of nitrogen (65 kg/ha) through urea was applied at first flower. Two hoeing were done at 60 and 85 days after planting to keep the weeds under control. Cotton growth parameters, yield attributing and seed cotton yield were recorded. Three pickings were done at 90 days stage of crop growth, nitrogen, phosphorous and potassium uptake (kg/ha) were determined.

RESULTS AND DISCUSSION

Growth parameters : The differential rate application of fertilizers at different depths had significant effect on plant height, dry weight and sympodial branches/ plant (Table 1). The maximum plant height, dry weight and sympodial branches/ plant were recorded with the placement of 70 per cent fertilizers at 10 cm and 30 per cent at 20 cm depths, throughout the period of crop growth. The band placement of fertilizers at two depths (70 % fertilizer at 15 cm + 30 % at 25cm depth; 50 % at 15 cm + 50 % at 25cm depth; 70 % at 10 cm + 30 % at 20cm depth and 50 % at 10 cm + 50 % at 20 cm depth) treatments produced significantly more plant height, dry weight and sympodial branches/ plant as compared to band placement of fertilizers at one depth (100 % fertilizer at 10 cm depth and 100 % fertilizer at 15 cm depth) treatments and control. The application of 100 per cent fertilizer at 10 or 15 cm depth produced growth parameters (plant height, dry weight and sympodial branches/ plant) *at par* with control. Non significant affect was observed on monopodial branches/plant due to differential rate application of fertilizer at different depths. The differential rate application of fertilizer at different depths resulted in to amelioration of compaction and more availability of fertilizer during various development stages of plants resulting into their vigorous growth. The present findings are in the conformity of Mandal and Thakur (2010).

Yield and yield attributing characters : The data relating to yield attributing characters (bolls/plant and 20 bolls weight) and seed cotton yield as influenced by differential rate of fertilizer application at different depth are given in Table 1. Of the seven fertilizer treatments, the placement of 70 per cent fertilizers at 10 cm and 30 per cent at 20 cm depths recorded significantly highest bolls/plant as compared to placement of (70% fertilizers at 15 cm and 30 % at 25 cm, placement of 50 % fertilizers at 15 cm and 50% at 25 cm and placement of 50 % fertilizers at 10 cm and 50 % at 20cm depths). The significantly lowest bolls/plant was recorded with placement of (100 % fertilizer at 15 cm) which was *at par* with placement of 100 per cent of fertilizer at 10 cm and broadcasting during both the years of crop growth. Among seven treatments of fertilizer placement, highest 20 bolls weight and seed cotton yield were recorded with the placement of (70 % fertilizers at 15cm and 30% at 25 cm depths, and found to be at par with placement of 50 % fertilizers at 15 cm and 50% fertilizers at 25 cm , placement of 70 % fertilizers at 10 cm and 30 % at 20 cm and placement of 50 % fertilizers at 10 cm and 50 % at 20cm depths). The band placement of fertilizers at two depths (70 % fertilizer at 15 cm + 30 % at 25cm depth; 50 % fertilizer at 15 cm + 50 % at 25cm depth; 70 % fertilizer at 10 cm + 30 % at 20cm depth and 50 % fertilizer at 10 cm + 50 % at 20 cm depth) treatments produced significantly more 20 bolls weight and seed cotton yield as compared to band placement of fertilizers at one depth (100 % fertilizer at 10 cm depth and 100 % fertilizer at 15 cm depth) treatments and control. The lowest 20 bolls weight and seed cotton yield were recorded in plants subjected to placement of (100 % fertilizer at 15 cm depth which was *at par* with placement of 100 % fertilizer at 10 cm and broadcasting). Higher number and weight of bolls in differential rate application of fertilizer at two different depths could be contributed to the better development of source as indicated by more plant height, dry weight and sympodial branches. Thus result better development of source and sink. This is evident from more plant height, dry weight and sympodial branches which lead to higher number of picked bolls/plant. A similar increase in lint yield as a result of the deep placement of K fertilizer and/ or lime was also reported by Tupper (1992).

Table 1. Effect of differential rate application of fertilizer at different depths with precision planter on growth parameters, yield attributes and seed cotton yield of cotton

Treatment	Plant height (cm) 150 Days after planting		Dry weight (Kg/ha) 150 Days after planting		Monopodial branches/ plant at harvest		Sympodial branches/ plant at harvest		Bolls / plant		20 bolls weight (g)		Seed cotton yield (kg/ha)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
T_1 Fertilizer (70 % at 15 cm + 30 % at 25cm depth)	143.1	135.4	1288	1222	2.8	2.7	27.2	26.5	69.9	67.9	73.9	72.5	2810	2650
T_2 Fertilizer (50 % at 15 cm + 50 % at 25cm depth)	136.9	132.2	1128	1100	2.7	2.9	26.6	25.5	68.3	66.4	73.9	71.9	2720	2600
T_3 Fertilizer (70 % at 10 cm + 30 % at 20cm depth)	145.4	138.3	1411	1388	2.8	2.6	28.4	26.8	74.5	70.9	74.6	72.5	2870	2650
T_4 Fertilizer 50 % at 10 cm + 50 % at 20 cm depth)	137.1	132.8	1168	1100	2.8	2.8	27.7	26.5	68.6	66.2	73.7	72.1	2700	2580
T_5 Fertilizer 100 % at 10 cm depth)	128.7	122.1	1000	998	3.3	3.1	24.5	23.8	60.5	61.2	72.7	69.1	2570	2460
T_6 Fertilizer 100 % at 15 cm depth)	126.8	123.6	1092	1025	3.2	3.2	24.2	24.3	60.3	60.6	71.6	68.6	2560	2440
T_7 Control (broadcasting) of fertilizer	128.6	124.5	981	917	3.3	3.1	24.7	24.1	62.1	62.0	72.6	70.1	2560	2450
CD (p = 0.05)	8.80	6.11	66.2	32.8	NS	NS	1.77	1.00	3.10	1.66	1.31	1.00	121	110

Table 2. Effect of differential rate application of fertilizers at different depths with precision planter on nutrients uptake by cotton at 90 days after planting

Treatments	Nutrients uptake(kg/ha)					
	Nitrogen		Phosphorus		Potassium	
	2009	2010	2009	2010	2009	2010
T_1 Fertilizer (70 % at 15 cm + 30 % at 25cm depth)	89.3	91.5	25.0	23.8	104.2	102.3
T_2 Fertilizer (50 % at 15 cm + 50 % at 25cm depth)	87.0	87.4	24.2	25.2	105.2	103.3
T_3 Fertilizer (70 % at 10 cm + 30 % at 20cm depth)	90.1	95.2	28.3	27.9	110.0	108.0
T_4 Fertilizer (50 % at 10 cm + 50 % at 20 cm depth)	85.0	84.2	27.0	27.3	107.5	105.0
T_5 Fertilizer (100 % at 10 cm depth)	75.3	74.1	22.1	21.8	98.1	99.1
T_6 Fertilizer (100 % at 15 cm depth)	78.5	76.2	22.4	22.9	96.5	95.9
T_7 Control (broadcasting of fertilizer)	77.5	75.2	22.0	21.9	99.0	95.0
CD (P = 0.05)	4.80	2.51	1.91	1.63	3.80	4.81

Nutrients uptake : The placement of (70 % fertilizers at 10 cm and 30 % at 20 cm depths) recorded significantly highest uptake of N, P and K as compared to placement of (70 % fertilizers at 15 cm and 30 % at 25 cm, placement of 50 % fertilizers at 15 cm and 50% at 25 cm and placement of 50 % fertilizers at 10 cm and 50 % at 20cm depths, Table 2) . The band placement of fertilizers at two depths (70 % fertilizer at 15 cm + 30 % at 25cm depth; 50 % fertilizer at 15 cm + 50 % at 25cm depth; 70 % fertilizer at 10 cm + 30 % at 20cm depth and 50 % fertilizer at 10 cm + 50 % at 20 cm depth) treatments resulted significantly more uptake of N, P and K as compared to band placement of fertilizers at one depth (100 % fertilizer at 10 cm depth and 100 % fertilizer at 15 cm depth) treatments and control. The significantly lowest uptake of N, P and K was recorded with placement of (100 % of fertilizer at 15 cm) which was *at par* with placement of (100 % of fertilizer at 10 cm and broadcasting).

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Productivity, quality and available nutrient of *Bt* cotton (*Gossypium hirsutum L.)* under different spacing and nutrient levels

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ABSTRACT: A study on of Performance of Bt cotton (*Gossypium hirsutum* L.) under different spacing and nutrient levels was conducted at Department of Agronomy, CCS, Haryana Agricultural University, Hisar during *kharif,* 2010. Seed cotton yield (kg/ha) was highest in closer spacing (100 x 40 cm) and was higher than 100x50 and 100 x 60 cm, respectively. Maximum oil content (%) and protein content (%) recorded in cotton seed in wider spacing (100 x 60 cm) which were significantly better than closer spacings (100 x 40 and 100 x50 cm). Plant spacing had a significant effect on N and K uptake but non significant effect on phosphorus uptake by the crop. Total NPK uptake cotton seed was highest in S_1 with a significant difference with S_2. Nitrogen uptake by crop was non significant. Total uptake of NPK by cotton crop under $F_1$and F_3 fertilizer doses did not differ significantly. Maximum potassium uptake was recorded in T_2 followed by T_1. The time of N fertilizer application did not differ in N, P and K uptake by cotton seed as well as total uptake by crop.

Key words: *Bt* cotton, nutrient uptake, productivity, spacing, quality

Productivity of cotton can be considerably improved by cultivation of *Bt* hybrids with suitable agronomic practices e.g. proper spacing, method of planting and nutrient management. Spacing affects plant growth and fruiting through its effects on the microclimate of the crop. Response of cotton to applied nutrients is governed by environment and cultural factors. Most of the cotton growing soils are deficient in N and P. Balanced fertilization of cotton is very essential for achieving high yields. Effect of nutrients may differ with spacing because of their profound impact on canopy structure, phonological behavior and fruiting pattern. It is, therefore, necessary to study the interacting influence of nutrients with spacing. The present investigation was planned to study the performance of Bt cotton (*Gossypium hirsutum* L.) under different spacing and nutrient levels.

The experiment was conducted at Agronomy Research Farm, CCS Haryana Agricultural University, Hisar, situated in the semi arid, sub tropical region of north western India, in the state of Haryana at $29^0$1022 N latitude, $75^0$4622 E longitude and at an altitude of 215.2 m above mean sea level. The experiment was laid out in split plot design with three replications during *kharif*, 2010. The Main plots treatments were spacing (cm) *viz.*, S_1:100 x 40, S_2:100 x 50 and S_3:100 x 60 and time of N fertilizer application (T_1:50% at flowering and 50% at square formation and T_2:25% at basal, 37.5% at flowering and 37.5% at square formation) Sub plots treatments were three nutrient levels (NPK) F_1: (75%RDF), F_2: (100%RDF) and F_3: (125%RDF). The soil of the experimental field was normal with respect to electrical conductivity, slightly high in pH, low in organic carbon and available nitrogen, medium in available phosphorus and high in available potash. Total of 709.3 mm rainfall was received during the crop season. RCH 134 was sown on 15^{th} May by dibbling. The N and P content in plant and soil were analyzed using standard procedures. Results were analyzed statistically.

Effect of spacing: Maximum plant height in 100 x 40 cm (142.77 cm) spacing was recorded followed by 100x50 (139.16 cm) and 100x60 (137.16 cm) (Table1). The increase in plant height was associated with increased internodal length. Similar results were observed by Manjappa *et al.,* (1997). Sympods/ plant was significantly higher in wider spacing 100x60 cm (21.12) than spacings of 100x50 cm (19.30) and 100x40 cm (19.26) (Table1). Similar results were reported by Buttar and Singh (2004). There was non significant effect of all the spacing on the boll weight. The closer spacing 100x40 cm gave higher seed cotton yield (3695 kg/ha) as compared to 100x50 cm (3290 kg/ha) and 100x60 cm (3185 kg/ha) spacings. This increase in seed cotton yield may be due to higher plant population over closer spacing. The results were also corroborated by Manjappa *et al.,* (1997). The closer spacing 100x40 cm gave higher cotton seed yield (2744 kg/ha) as compared to 100x50 cm (2456 kg/ha) and 100x60 cm (2385 kg/ha). Similar results were found by Lokhande *et al*., (2004) who reported that narrow spacing of 67.5 x 60 cm resulted in significantly higher cotton seed yield (814 kg/ha) over wider spacing 100 x 60 cm (727 kg/ha). The closer spacing 100x40 cm gave higher lint yield (905 kg/ha) as compared to 100x50 cm (785 kg/ha) and 100x60 cm (763 kg/ha).

Available N, P and K in soil after harvest of crop were significantly influenced by plant geometry (Table3). The 100x60 cm spacing (S_3) exhibited significantly higher available N, P and K in soil (136:16:301 kg/ha) than closer spacings. Next best treatment was 100x50 cm (S_2) which was significantly superior to closer spacing of 100x40 cm (S_3). This might be due to higher seed cotton yield (kg/ha) hence nutrient removal at closer spacing is high (Table 3).

Time of N fertilizer application : Application of N fertilizer in three splits recorded significantly higher plant height (140.51 cm) and sympods/plant as against two splits of N fertilizer application. There was non significant effect of N fertilizer application on the boll weight (Table1). The seed cotton, cotton seed and lint yields recorded with three split dose of N fertilizer application were significantly higher over two splits of N fertilizer application (Table1).

Difference in available N, P and K in soil after harvest of crop due to split doses of N fertilizer was also significant. Maximum available N, P and K in soil (132:15:296 kg/ha) was observed with 2 split doses of N application (T_1) as compared to 3 split doses of N application (T_2) (Table3).

Effect of fertilizer: The higher dose of fertilizer (125% RDF) per cent resulted higher in plant height over 75 per cent recommended dose of fertilizer (Table1). Similar results were reported by Ram and Giri (2006). Sympods/plant increased with increasing doses of fertilizers on up to 100 per cent recommended dose of fertilizer (20.38). Similar results were reported by Lokhande *et al.,* (2004). There was non significant effect of all the nutrient levels on

Table 1. Growth, yield attributes, seed cotton yield, cotton seed and lint yield of *Bt* cotton (*Gossypium hirsutum* L.) under different spacing and nutrient levels

Treatments	Plant height (cm)	Sympods/ plant	Boll/ weight (g)	Seed cotton yield (kg/ha)	Cotton seed yield (kg/ha)	Lint yield (kg/ha)
Spacing (cm)						
S_1: 100x40	142.77	19.26	2.92	3695	2744	905
S_2 : 100x50	139.16	19.30	2.95	3290	2456	785
S_3 : 100x60	137.16	21.12	3.04	3185	2385	763
SE m+	0.43	0.12	0.21	70	14.81	5.50
C.D. (p=0.05)	1.25	0.36	NS	276	43.23	16.17
Time of N fertilizer application						
T_1 (50%at lowering and 50% at square formation)	138.88	19.32	2.92	3180	2413	748
T_2 (25% at sowing and 37.5% at square formation and 37.5% at flowering)	140.51	20.46	2.97	3590	2643	872
SE m+	0.35	0.04	0.43	48	12.21	3.21
C.D. (p=0.05)	1.02	0.14	NS	140	35.41	9.05
Fertilizers levels						
F_1: RDF (75 %)	135.66	19.29	2.94	3155	2404	697
F_2: RDF (100%)	139.94	20.38	2.98	3515	2638	844
F_3: RDF (125%)	143.50	20.04	2.99	3345	2542	762
SE m+	0.61	0.05	0.35	59	10.81	5.82
C.D. (p=0.05)	1.77	0.17	NS	172	31.43	17.13

Table 2. Quality parameters of *Bt* cotton (*Gossypium hirsutum* L.) under different spacing and nutrient levels

Treatments	Oil content (%)	Protein content (%)	Micronaire value (10^6 mm/in)	G.O.T (%)	2.5 per cent span length (mm)	Fibre strength (g/tex)
Spacing (cm)						
S_1 : 100x40	22.9	13.95	3.94	32.98	29.40	22.01
S_2 : 100x50	23.2	13.35	3.92	31.55	29.97	22.56
S_3 : 100x60	23.7	14.25	4.17	31.85	30.14	23.26
SE m+	0.06	0.10	0.03	0.27	0.31	0.23
C.D. (p=0.05)	0.2	0.3	NS	NS	NS	0.67
Time of N fertilizer application						
T_1 (50%at lowering and 50% at square formation)	22.3	13.58	3.92	30.25	29.80	21.98
T_2 (25% at sowing and 37.5% at square formation and 37.5% at flowering)	22.6	13.85	3.99	32.50	29.92	22.30
SE m+	0.02	0.04	0.03	0.34	0.31	0.22
C.D. (p=0.05)	NS	NS	NS	NS	NS	NS
Fertilizers levels						
F_1: RDF (75 %)	22.5	12.5	3.90	30.45	30.96	22.51
F_2: RDF (100%)	22.8	14.1	4.07	31.85	30.71	21.77
F_3: RDF (125%)	22.9	17.7	4.24	30.75	30.60	21.96
SE m+	0.07	0.24	0.04	0.39	0.32	0.20
C.D. (p=0.05)	NS	0.7	NS	NS	0.96	NS

the boll weight. Seed cotton yield (kg/ha) was higher with 100 per cent RDF (3515 kg/ha) followed by 125 per cent RDF (3345 kg/ha) and 75 per cent RDF (3155 kg/ha). Similarly, cotton seed yield (kg/ha) was maximum at 100 per cent RDF (2638 kg/ha) followed by 125 per cent RDF (2542 kg/ha) and 75 per cent RDF (2404 kg/ha). Similar results were obtained by Srinivasulu *et al.,* (2006). Lint yield increased with increasing dose of fertilizer 75 per cent RDF (697 kg/ha) to 100 per cent RDF (844 kg/ha). The yield decreased slightly at 125 per cent RDF (762 kg/ha) (Table 1).

Significantly higher available N, P and K in soil after harvest of crop was found with 125 per cent RDF, which is significantly superior over 75 per cent RDF and 100 per cent RDF (Table 3). The above results are also

Table 3. The available N P K (kg/ha) of *Bt* cotton (*Gossypium hirsutum* L.) under different spacing and nutrient levels

Treatments	Nitrogen	Phosphorus	Potassium
Spacing (cm)			
S_1 : 100x40	122	13	285
S_2 : 100x50	126	14	288
S_3: 100x60	136	16	301
SE m+	0.31	0.04	0.22
C.D. (p=0.05)	0.90	0.12	0.65
Time of N fertilizer application			
T_1 : 50% at flowering and 50% at square formation	132	15	296
T_2 : 25% at sowing and 37.5% at flowering and 37.5% at square formation	124	13	287
SE m+	0.25	0.03	0.18
C.D. (p=0.05)	0.72	0.10	0.53
Nutrient levels			
F_1 : RDF (75%)	128	14	291
F_2 : RDF (100%)	121	13	285
F_3 : RDF (125%)	134	15	299
SE m+	0.19	0.08	0.21
C.D. (p=0.05)	0.55	0.24	0.60

corroborated by the findings of Katkar *et al.,* (2002).

Quality parameters: Various crop geometry and fertilizer levels did not show any significant effect on micronaire value, 2.5 per cent span length and GOT (Table2). Fibre strength (g/tex) was maximum under the spacing of 100x60 cm (23.26 g/tex), 2.5 per cent span length was highest at 75 per cent RDF (30.96 mm) and further was decreased with the application of fertilizer. There was non significant affect of time of N fertilizer application on the quality parameters i.e. micronaire value, 2.5 per cent span length and fibre strength (g/tex) (Table2). Srinivasulu *et al.,* (2006) reported that fibre strength, ginning outturn and micronaire value did not influenced by hybrids, spacings and nitrogen levels. Significantly more oil content was observed in 100x60 spacing than closer spacing. Oil content was also did not affected by split application of N fertilizer and fertilizer levels. Highest protein content was recorded in 100x60 cm plant spacing as compared to other. However, the difference in protein content was significant between S_3 and S_2 and S_1 and S_2. Significantly high protein content was recorded in higher dose of fertilizers *i.e.* 125 per cent RDF followed by F_2 and F_1.

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Screening of cotton genotypes for water stress tolerance

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ABSTRACT : Twenty entries / genotypes of *Gossypium hirsutum* were evaluated under stress (rainfed) and normal (irrigated) condition at Navsari Agricultural University, Main Cotton Research Station, Surat during 2009-2010. The plant height, stomatal conductance, transpiration rate, relative water content (RWC), biomass, boll weight, number of bolls and yield significantly reduced due to moisture deficit. Usual significant differences amongst genotypes were observed in these traits except stomatal conductance. Bihani 161, GTHV 0/35, GTHV 02/45, KH 155, GJHV 374 and CPD 824 produced more biomass under stress and or exhibited a minimum reduction in the same. Bihani 161, GJHV 374, GTHV 0/35, ADB 102 and KH 155 performed better under stress and gave maximum yield stability under stress. Under irrigated condition seed cotton yield significantly and positively associated with number of bolls, harvest index, biomass and boll weight. Whereas under rainfed condition it had significant and positive correlation with number of bolls, biomass, harvest index, relative water content and plant height.

Key words : Drought, cotton and water stress

Cotton is major fibre crop of global significance. India is the only country, where all the four cultivated species (*i.e. Gossypium harbaceum* L., *G. arboreum* L., *G. hirsutum* L. and *G. barbadense* L.) are grown between 10^{o} to 30^{o} latitude and 70^{o} to 80^{o} longitude. It ranks second in production of seed cotton, but the production/ unit area is low as compared to other countries. The percentage of irrigated area is much lower in the central (23 %) and southern zones (40 %). Water availability is a determining factor in plant growth and yield of all agricultural commodities while demands on water resources for agricultural purpose is increasing. Declining water availability, changing climatic conditions and increasing human demand are limiting its availability for agriculture. Drought tolerance is a complex agronomic trait with multigenic components which interact in a holistic manner in plant system. Therefore selection for drought tolerance is a continuous interest of cotton improvement. Attempts have been made to develop water stress tolerant varieties and hybrids with good success but enough scope is there to develop better and tolerant varieties as also to find out physiological basis of tolerance so that it could be incorporated in future varieties.

Since inadequate water has a broad physiological spectrum affecting many processes, it is difficult to assess the contribution of individual process to plant yield. One approach for evaluations the contribution of individual process to inadequate water losses has been to compare crop varieties that show differential responses to drought stress. The present investigation was initiated to understand the impact of moisture stress on the basic yield components and physiological parameters. The selection of parents with high diversity is a basic requirement in any successful programme for selecting high yielding genotypes for drought tolerance. Therefore the objective of present study was to access genotypic variation for drought tolerance using various drought susceptibility indices.

A field experiment was carried out at Navsari Agricultural University, Main Cotton Research Station, Surat during *kharif,* 2009-2010 to screen cotton genotypes for water stress tolerance. Twenty entries / genotypes of *G. hirsutum* (*viz.,* PH 1024, CPD 824, DHH 0761, DHH 0762, RAHH 231, CPD 817, GSHV 152, GSHV 01/ 26, GJHV 374, GTHV 0/35, GTHV 02/45, KH 155, WGHH 411, ARBH 813, ADB 102, Bihani 161, NH 630, H 1236, LRA 5166 {Zonal check} and G.Cot.16 {Local check}) were evaluated under stress (rainfed) and normal (irrigated) condition. The experimental soil was fertilized with 10 t FYM/ ha uniformly at the time of land preparation. The chemical fertilizer was applied @ 240:00:00 kg NPK/ ha in the form of urea at 25 to 30 days interval starting from 20 DAS. All the necessary plant protection measures were taken as and when required for the control of insect pests. In general, the field was free from any serious pest and disease. The data on plant height, sympodia, fruiting forms/plant. Cotton seed yield was recorded on the basis of plot area and the whole plot pertaining to the crop was picked three times in each treatment. The photosynthetic rate, stomatal conductance and transpiration rate were measured using CIRAS 1A photosynthetic system.

Plant height: The results of the present study showed that at 94 DAS plant height under stress did not show significant decline, probably due to less severity of stress as available soil moisture was 22 per cent (Table 1). As the crop progressed, the available soil moisture declined to 18 per cent and 12 per cent at 134 DAS and at harvest, respectively, compared to 23.3 per cent and 18 per cent in irrigated. This reflected on plant height, which significantly decreased at 134 DAS and at harvest under stress compared to irrigated. Patel *et al.*, (2008) and Kumar and Bardhan (2009) reported that plant height significantly reduces under stress. This decrease in plant height under water stress might be due to suppression of cell expansion and cell growth, or due to low turgor pressure. Variation in plant height amongst genotypes has been widely reported by Kumar and Bardhan (2009). Response of different genotypes to stress was found significant. Some of the genotypes like GTHV 0/35, GSHV 01/26, GTHV 02/45, WGHH 411 and Bihani 161 did not show reduction under stress at 134 DAS and at harvest *vis-à-vis* their irrigated counterpart, unlike other genotypes which significantly reduced in height. Reduction in plant height is usually due to reduction in number of nodes. Pettigrew (2004) reported that plants receiving more water produce more nodes resulting in more plant height.

Number of nodes/plant: Result pertaining to number of nodes per plant clearly indicated significant reduction under stress (17.9) compared to irrigated condition (20). The study also showed (Table 1) significant differences amongst the genotypes. The findings are in corroboratory with earlier reports of Pettigrew (2004). Genotypes RAHH 231, CPD 817, GJHV 374, GTHV 0/35, GTHV 02/45 and Bihani 161 recorded significantly higher nodes.

Relative water content (RWC): Physiological parameter that describes the water status of plants is RWC. The RWC is a measure of the amount of water present in the leaf tissue. It is reported that high RWC is a resistance mechanism to drought and that high RWC is the result of more osmotic regulation or less elasticity of tissue cell wall. In the present study (Table 1), RWC significantly declined due to stress both at 94 DAS and at 134 DAS as also reported by Nepomuceno *et al.*, (1998) and Kumar and Bardhan (2009). However, greater reduction was observed at 134 DAS. The genotypic differences in overall RWC were found significant which is quite possible because of different genetic background of the material used and their response to water. However genotypes behaved little differently at 134 DAS than the overall pattern which showed greater reduction in RWC at 134 DAS than at 94 DAS, like in DHH 0761, DHH 0762, CPD 817, GJHV 374, ARBH 813 and LRA 5166. Compared to mean reduction of 8 per cent at 134 DAS, GJHV 374, ARBH 813, Bihani 161 and DHH 0761 exhibited less than 6 per cent reduction or maintained a higher RWC in the same situation pointing to their better tolerance. Kumar and Bardhan (2009) and Nepomuceno *et al.*, (1998) also reported similar results.

Photosynthetic rate: The result of the present study showed that (Table 2) at 94 DAS, photosynthesis did not decline significantly; probably due to less severity of stress as available soil moisture was 22 per cent. As the crop progressed, the available soil moisture declined to 18 per cent at 134 DAS, compared to 24.7 in 23.3 per cent in irrigated. This reflected on photosynthesis, which significantly decreased under stress compared to irrigated at 134 DAS. McMichael and Hesketh (1982) and Nepomuceno *et al.*, (1998) reported that photosynthesis significantly reduces under stress. This decrease in photosynthesis under water stress was due to or led to photo inhibition opined that decrease in photosynthesis under stress corresponds with decrease in stomatal conductance, as also observed in the present investigation. The result clearly showed variations in genotypes at both stages. Where as at 94 DAS WGHH 411, KH 155, GTHV 0/35, GTHV 02/45 and DHH 0762 exhibited lesser reduction compared to 4 per cent mean.

At 134 DAS genotypes ADB 102 closely followed by CPD 817, WGHH 411, KH 155, GJHV 152, DHH 0762, RAHH 231 and LRA 5166 exhibited lesser reduction than 10 per cent mean. These genotypes also maintained higher photosynthetic rate, than the mean. Variation in photosynthesis amongst the genotypes has been widely reported by Nepomuceno *et al.,* (1998). Therefore it can be inferred that water stressed plants had less photosynthesis compared with irrigated plants but tolerant genotypes either maintained photosynthesis near unstressed condition or showed minimum reduction in the same as also stated by Nepomuceno *et al.*, (1998).

Stomatal conductance: The result indicated that (Table 2) at both the growth stages stomatal conductance differed significantly due to irrigation. McMichael and Hesketh (1982), Ephrath *et al.*, (1990) and Pettigrew (2004) stated stomatal conductance to decrease substantially under stress as compared to irrigated plants. The results also showed significant variations in stomatal conductance amongst the genotypes at 94 DAS. Variation in stomatal conductance amongst the genotypes has been reported by Nepomuceno *et al.,* (1998) and Kumar and Bardhan (2009), which could be because of genetic background as well as parameter like RWC. The relation of stomatal conductance with transpiration rate was found significantly positive which is quite expected.

Transpiration rate: In the present study (Table 2), transpiration rate significantly declines due to stress both at 94 DAS and at 134 DAS. Kumar and Bardhan (2009) also reported decline in transpiration rate due to stress. However greater reduction was observed at 134 DAS. As the crop advanced the transpiration rate decreases. Nepomuceno *et al.,* (1998) also observed similar trend. The genotypic differences in overall transpiration rate were found significant, which is quite possible because of different genetic background of the material used and their response to water.

It was interesting to observe that genotypes Bihani 161, NH 630, KH 155, RAHH 231, CPD 824 exhibited > 25 per cent reduction in transpiration under stress compared to 17 percent mean reduction at 134 DAS. At the same time, there have been genotypes like GSHV 152, GJHV 374, PH 1024 which showed < 9 per cent reduction in transpiration rate in similar situation, indicating that genotypes manifested their water balance through a set of mechanism.

Yield and yield attributes : Various yield contributing characters and yield of cotton recorded in the present investigation were significantly influence barring harvest index.

Number of bolls: The result clearly showed that (Table 2) bolls/plant significantly reduced under stress (26.2) compared to irrigated condition (36.6). Similar results were observed by Kumar *et al.*, (2003), Pettigrew (2004). The differences in bolls amongst the genotypes were found to be significant, which is widely reported earlier by Kumar and Bardhan (2009). The genotypes responded differently to irrigation situation. Contrary to the overall effect indicating significant reduction in no. of bolls under stress, genotypes ARBH 813, ADB 102 and Bihani 161 did not show only such effect.

Boll weight: Boll weight significantly decreased due to stress also observed similar result. The result indicated that (Table 2) irrespective of the genotypes boll weight was significantly reduced under stress (2.24 g) compared to irrigated condition (2.50 g). In the present investigation it appears that greater photosynthetic rate in irrigated basically led to higher biomass and ultimately boll weight and/ or boll number. Bharadwaj and Kalindi (1986) reported that greater boll weight is the result of higher biomass, which may be because of higher photosynthetic rate which the present findings substantiate. The result also showed significant differences in boll weight amongst the genotypes. The genotypes showed significant variations in the mean boll weight which ranged between 2.04 (ARBH 813) to 2.75 (CPD 824). Variation in boll weight amongst the genotypes is widely reported by Kumar *et al.,* (2003) and Kumar and Bardhan (2009). Interaction was not found significant between genotypes and irrigation, however, less reduction in boll weight was seen in WGHH 411 closely followed by ARBH 813, G.Cot.16, KH 155, GSHV 01/26, RAHH 231, H 1236, LRA 5166, CPD 817, DHH 0762 and GSHV 152 than mean of all

Table 1. Effect of water stress on plant height, no. of nodes/plant and RWC in different cotton genotypes

Genotypes	Plant height (DAS)						At harvest			Nodes/plant			RWC (DAS)					
	94			134									94			134		
	IR	RF	**Mean**	IR	RF	**Mean**	IR	RF	**Mean**	IR	RF	**Mean**	IR	RF	**Mean**	IR	RF	**Mean**
PH 1024	63	59	**61**	98	72	**85**	102	74	**88**	17.7	19.0	**18.3**	84.3	78.9	**81.6**	78.3	68.0	**73.1**
CPD 824	84	71	**77**	113	87	**100**	123	93	**108**	17.3	19.3	**18.3**	82.9	77.0	**79.9**	80.3	70.2	**75.3**
DHH 0761	76	71	**73**	110	86	**98**	116	90	**103**	16.7	20.6	**18.6**	87.0	79.8	**83.4**	81.0	77.0	**79.0**
DHH 0762	72	69	**70**	107	87	**97**	115	90	**102**	19.7	19.3	**19.5**	85.0	77.1	**81.1**	79.4	74.2	**76.8**
RAHH 231	76	71	**73**	114	89	**101**	118	91	**104**	23.2	20.1	**21.7**	84.7	76.6	**80.6**	78.9	69.7	**74.3**
CPD 817	79	76	**77**	126	92	**109**	132	95	**113**	23.1	23.0	**23.1**	84.7	77.7	**81.2**	81.3	75.0	**78.2**
GSHV 152	71	67	**69**	116	92	**104**	121	96	**108**	18.7	18.2	**18.4**	87.0	80.0	**83.5**	81.5	72.4	**77.0**
GSHV 01/26	71	68	**69**	110	101	**105**	112	102	**107**	19.6	19.3	**19.4**	86.5	80.1	**83.3**	80.0	72.6	**76.3**
GJHV 374	69	64	**66**	113	101	**107**	120	106	**113**	19.7	18.8	**19.2**	86.6	82.1	**84.4**	82.4	80.1	**81.3**
GTHV 0/35	66	63	**64**	97	89	**93**	107	96	**101**	22.0	22.1	**22.1**	82.3	79.6	**81.0**	80.4	74.6	**77.5**
GTHV 02/45	73	71	**72**	102	94	**98**	107	98	**102**	22.3	18.3	**20.3**	81.9	76.9	**79.4**	80.0	74.7	**77.3**
KH 155	75	72	**73**	113	86	**99**	116	88	**102**	18.0	18.1	**18.1**	83.0	78.9	**80.9**	78.1	71.3	**74.7**
WGHH 411	83	78	**80**	114	107	**109**	123	112	**117**	15.0	16.4	**15.7**	82.0	80.1	**81.0**	80.2	75.7	**78.0**
ARBH 813	86	75	**80**	116	98	**107**	132	107	**119**	18.1	18.2	**18.1**	82.5	78.5	**80.5**	79.1	76.3	**77.7**
ADB 102	70	67	**68**	106	96	**101**	119	103	**111**	17.6	19.1	**18.4**	85.5	79.0	**82.3**	80.7	71.9	**76.3**
Bihani 161	78	75	**76**	111	105	**108**	122	115	**118**	20.2	20.3	**20.3**	83.4	80.2	**81.8**	81.1	77.1	**79.1**
NH 630	73	69	**71**	115	90	**102**	129	97	**113**	19.3	20.6	**19.9**	84.8	79.5	**82.2**	78.5	67.6	**73.1**
H 1236	73	68	**70**	108	96	**102**	112	98	**105**	19.7	16.3	**18.0**	86.6	79.8	**83.2**	78.6	71.9	**75.2**
LRA 5166	74	70	**72**	111	102	**106**	118	105	**111**	17.7	20.0	**18.8**	86.9	80.2	**83.6**	79.9	74.4	**77.2**
G. Cot. 16	69	66	**67**	104	94	**99**	112	100	**106**	19.3	17.2	**18.3**	83.7	80.0	**81.9**	80.4	74.3	**77.4**
Mean	74	70	**72**	110	93	**101**	118	98	**108**	17.7	19.0	**18.3**	84.6	79.1	**81.8**	80.0	73.5	**76.7**
	I		V	I		V	I		V	I		V	I		V	I		V
S. Em.±	1.0		2.6	1.1		2.8	1.3		2.7	0.36		0.84	0.4		1.0	0.4		1.2
C.D. (p=0.05)	NS		7.4	7.0		7.8	9.9		8.1	NS		2.37	2.5		2.9	2.5		3.5
C.V. (%)	11.1		8.9	8.8		6.7	11.7		6.5	14.8		10.8	3.8		3.0	4.2		4.0
IxV		NS			11.1			11.5			NS			NS			NS	

Table 2. Effect of water stress on photosynthetic rate, stomatal conductance and transpiration rate in different cotton genotypes

Genotypes	Photosynthetic rate (DAS)						Stomatal conductance (DAS)						Transpiration rate(DAS)					
	94			134			94			134			94			134		
	IR	RF	**Mean**	IR	RF	**Mean**	IR	RF	**Mean**	IR	RF	**Mean**	IR	RF	**Mean**	IR	RF	**Mean**
PH 1024	32.1	31.1	**31.6**	28.2	24.2	**26.2**	666	641	**654**	519	470	**495**	8.93	7.13	**8.03**	4.43	4.17	**4.3**
CPD 824	33	30.1	**31.5**	26.5	20.6	**23.5**	658	589	**624**	556	425	**491**	8.33	7.2	**7.77**	4.4	3.2	**3.8**
DHH 0761	31.4	29.7	**30.5**	26.5	23.3	**24.9**	661	567	**614**	530	419	**475**	8.83	8.17	**8.5**	4.6	4.17	**4.39**
DHH 0762	32	31.7	**31.9**	27	25	**26**	650	629	**640**	514	463	**489**	9.13	7.93	**8.53**	5.13	3.93	**4.53**
RAHH 231	31.1	29.7	**30.4**	27.5	25.1	**26.3**	618	599	**609**	498	474	**486**	8.6	7.4	**8**	4.73	3.5	**4.12**
CPD 817	30.9	29.4	**30.1**	26.5	25.1	**25.8**	674	646	**660**	535	476	**506**	9.23	8.97	**9.1**	5.37	4.7	**5.04**
GSHV 152	31.7	29.5	**30.6**	26.5	24.5	**25.5**	637	598	**618**	513	455	**484**	8.28	8.17	**8.23**	4.3	4.17	**4.24**
GSHV 01/26	31.1	29.4	**30.3**	26.7	24.1	**25.4**	607	581	**594**	491	455	**473**	9.1	8.2	**8.65**	5.1	3.93	**4.52**
GJHV 374	32.3	30.1	**32**	27.3	23.6	**25.4**	661	599	**630**	518	427	**473**	9	8.83	**8.92**	5	4.67	**4.84**
GTHV 0/35	31.2	30.8	**30.7**	27.6	24.6	**26.1**	665	607	**636**	520	442	**481**	9.3	8.73	**9.02**	5.3	4.73	**5.02**
GTHV 02/45	30.9	30.5	**30.8**	28.1	24.7	**26.4**	651	592	**622**	517	454	**486**	9.13	8.97	**9.05**	5	4.43	**4.72**
KH 155	31.4	30.9	**31.2**	27.7	25.9	**26.8**	666	614	**640**	520	460	**490**	8.4	7.27	**7.84**	4.6	3.27	**3.94**
WGHH 411	31.9	31.7	**31.8**	27.4	25.8	**26.6**	640	600	**620**	515	446	**481**	8.67	8.37	**8.52**	4.9	4.2	**4.55**
ARBH 813	30.1	28.3	**29.2**	27.9	25.6	**26.7**	665	622	**644**	512	441	**477**	9.1	8.53	**8.82**	5.1	4.53	**4.82**
ADB 102	30.5	29.5	**30**	26.6	25.2	**25.9**	668	631	**650**	522	475	**499**	8.9	8.13	**8.52**	5	4.07	**4.54**
Bihani 161	30.8	29.7	**30.2**	27.6	23.7	**25.6**	645	585	**615**	531	429	**480**	8.97	6.97	**7.97**	5.1	3.43	**4.27**
NH 630	30.9	29.6	**30.3**	27.7	24.4	**26**	649	588	**619**	509	453	**481**	8.5	6.5	**7.5**	4.5	3.3	**3.9**
H 1236	30.6	27.5	**29**	27.8	24.6	**26.2**	657	587	**622**	507	433	**470**	8.93	8.37	**8.65**	4.93	4.17	**4.55**
LRA 5166	30.5	29.2	**29.9**	27.7	25.3	**26.5**	639	600	**620**	518	475	**497**	9.07	8.4	**8.74**	5.07	4.4	**4.74**
G. Cot. 16	30.7	29.8	**30.3**	26.7	24	**25.4**	643	561	**602**	512	427	**470**	8.83	8.77	**8.8**	4.87	3.97	**4.42**
Mean	**31.3**	**29.9**	**30.6**	**27.3**	**24.5**	**25.9**	**651**	**602**	**627**	**518**	**450**	**484**	**8.86**	**8.05**	**8.46**	**4.87**	**4.04**	**4.46**
	I		V	I		V	I		V	I		V	I		V	I		V
S. Em.±	0.3		0.57	0.16		0.43	8		13	4.9		13.2	0.11		0.24	0.09		0.21
C.D. (p=0.05)	NS		1.61	0.98		1.21	48.9		36.5	29.7		NS	0.69		0.68	0.55		0.59
C.V. (%)	7.67		4.59	4.86		4.1	9.9		5.1	7.8		6.7	10.5		7.07	15.8		11.5
IxV		NS			NS			NS			NS			NS			NS	

Table 3. Effect of water stress on yield attributing characters in different cotton genotypes

Genotypes	Number of bolls			Boll weight			Yield			Biomass			Harvest index		
	IR	RF	**Mean**	IR	RF	**Mean**	IR	RF	**Mean**	IR	RF	**Mean**	IR	RF	**Mean**
PH 1024	38.8	24	**31.4**	2.65	2.33	**2.49**	103	67	**85**	285	190	**238**	36.3	37.3	**36.8**
CPD 824	36.3	21.8	**29**	2.93	2.57	**2.75**	106	55	**81**	231	188	**210**	47.6	30.2	**38.9**
DHH 0761	40.3	26.7	**33.5**	2.55	2.27	**2.41**	107	61	**84**	261	190	**226**	41.1	32	**36.5**
DHH 0762	32.6	20.9	**26.8**	2.52	2.3	**2.41**	81	48	**65**	243	111	**177**	33.3	44.6	**38.9**
RAHH 231	37.4	15.4	**26.4**	2.58	2.4	**2.49**	94	37	**66**	247	117	**182**	38.5	32.6	**35.6**
CPD 817	32.8	24	**28.4**	2.52	2.32	**2.42**	82	55	**69**	221	134	**178**	37.1	41.4	**39.2**
GSHV 152	36.7	17.8	**27.3**	2.68	2.42	**2.55**	98	44	**71**	238	121	**180**	41.1	35.8	**38.5**
GSHV 01/26	37.8	26.8	**32.3**	2.66	2.49	**2.58**	100	67	**84**	254	183	**219**	39.4	37.2	**38.3**
GJHV 374	39.9	31.3	**35.6**	2.49	2.24	**2.37**	99	84	**92**	178	152	**165**	45.5	46.6	**46.1**
GTHV 0/35	36.8	28.5	**32.6**	2.42	2.03	**2.23**	90	76	**83**	213	187	**200**	42.4	40.7	**41.5**
GTHV 02/45	37.5	31.7	**34.6**	2.97	2.04	**2.51**	111	64	**88**	223	197	**210**	46.7	32.8	**39.8**
KH 155	39.2	32.2	**35.7**	2.4	2.25	**2.33**	93	72	**83**	249	208	**229**	40.3	36.5	**38.4**
WGHH 411	36.8	28.5	**32.7**	2.42	2.39	**2.41**	89	81	**85**	216	181	**199**	41.2	46.4	**43.8**
ARBH 813	36.8	34.4	**35.6**	2.07	2	**2.04**	77	67	**72**	194	151	**173**	40.2	44.4	**42.3**
ADB 102	31.6	26.9	**29.3**	2.35	2.03	**2.19**	74	53	**64**	172	148	**160**	44	36.7	**40.3**
Bihani 161	29.8	28.3	**29**	2.74	2.4	**2.57**	80	76	**78**	254	236	**245**	31.9	32.3	**32.1**
NH 630	41.2	24.7	**33**	2.35	2	**2.18**	96	56	**76**	248	153	**201**	39.7	37.8	**38.8**
H 1236	37.9	20.8	**29.4**	2.25	2.08	**2.17**	85	56	**71**	231	136	**184**	37	43.1	**40.1**
LRA 5166	35.5	29.4	**32.5**	2.45	2.24	**2.35**	85	66	**76**	223	163	**193**	38.4	41.1	**39.8**
G. Cot. 16	36.6	29	**32.8**	2.08	2.01	**2.05**	87	71	**79**	216	169	**193**	40.8	42.7	**41.7**
Mean	**36.6**	**26.2**	**31.4**	**2.5**	**2.24**	**2.37**	**92**	**63**	**78**	**229**	**165**	**197**	**40.1**	**38.6**	**39.4**
	I		V	I		V	I		V	I		V	I		V
S. Em.±	0.6		1.4	0.04		0.13	1.3		3.2	3.6		7.3	2.3		3.5
C.D. (p=0.05)	3.9		4	0.26		0.37	7.8		8.9	19.2		20.6	NS		NS
C.V. (%)	15.8		11.1	14		13.8	12.8		10	12.4		9	18.5		15
IxV	5.7			NS			12.62			29.7			NS		

genotypes.

Biomass: Biomass of plant significantly differed due to the irrigation treatment. The result indicated that (Table 4) the average biomass/plant under irrigated (229 g) was reduced by significant margin under stress (165 g). In irrigated condition, it ranged between 172 g/plant (ADB 102) to 285 g/plant (PH 1024), while under rainfed condition, it ranged from 111 g/ plant (DHH 0762) to 236 g/plant (Bihani 161). Quisenberry *et al.,* (1985), Kumar *et al.,* (2003) and Kumar and Bardhan (2009) have also reported that biomass reduced under stress. The study showed that biomass was positively correlated with root length and plant height. Similar finding have been reported earlier by Reddy *et al*., (2004). Result of present study showed that decrease in photosynthesis under stress corresponds with decrease in biomass. Significant differences in biomass amongst the genotypes were observed in the present investigation. Similar variations have been obtained by Quisenberry (1985). This could be because of variations in photosynthesis and growth owing to genetic background. Whereas significant reduction in biomass was observed under stress, genotypes GJHV 374, GTHV 0/35, GTHV 02/45, ADB 102 and Bihani 161 did not show significant reduction. Such a differential response of genotypes was earlier reported by Haman (2008) and Quisenberry *et al*., (1985), Kumar *et al.,* 1987 and Kumar *et al*., 2003).

Seed cotton yield: It is clear from the result that (Table 2) water stress brought about significant reduction in yield compared to irrigated condition. In irrigated condition, mean yield of twenty genotypes was 92 g, ranging from 74 (ADB 102) to 111 g/plant (GTHV 02/45), Under rainfed condition, the mean yield was 63 ranging from 37 (RAHH 231) to 84 g/plant (GJHV 374) and only one entry recorded higher (GJHV 374) which could be because of low photosynthetic rate and biomass produced as brought out in earlier discusion. Kumar and Bardhan (2009) have earlier reported significant reduction in yield under stress. Genotypic differences in seed cotton yield as observed in the present study have been reported by many workers (Kumar *et al*., (2003) and Kumar and Bardhan (2009). Genotypes Bihani 161, WGHH 411 and ARBH 813 did not show significant reduction in the same situation. Therefore could be considered as stress tolerant. Quisenberry *et al.,* (1976) also found that some genotypes show minimum reduction whereas other shows vary high reduction in similar stress condition.

The interaction was found to be significant, in which genotypes responded differently to irrigation situation contrary to the overall effect. Whereas significant reduction in seed cotton yield was observed under stress.

Harvest Index: The irrigated and rainfed condition of cotton did not reveal significant differences in harvest index. The genotypes also did not show significant difference. In irrigated condition (Table 3), mean harvest index was 40.1 ranging from 31.9 in Bihani-161 to 46.7 in GTHV 02/45 while under rainfed condition; the mean was 38.6 ranging from 30.2 in CPD 824 to 46.6 in GJHV 374. Gerik *et al.,* (1996) observed that short duration drought tolerant variety used more water at a faster rate than its sister line under stressed conditions thus the harvest index of irrigated cotton consistently higher than rainfed regimes. At the same time genotypes like PH 1024, DHH 0762, GJHV 374, WGHH 411, ARBH 813, H 1236, LRA 5166 and G.Cot.16 which recorded higher harvest index in same condition. This might be due to shedding of foliage under stress, resulting in lesser biomass and ultimately higher harvest index.

In conclusion, this experiment demonstrated that intraspecific genetic variation for drought tolerance exit amongst cotton genotypes. If the variation described can be transcribed to variety, lint yield may be increased under large rainfed cotton growing area of the country. These results indicate that potential for improvement exists in the cotton germplasm for efficient water use but further evaluations are necessary before improved agronomic types can be developed

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Field evaluation of portable handheld type cotton picking machines for different cotton varieties

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ABSTRACT : Cotton is picked either manually, pneumatically or mechanically such as stripper and picker. These harvesters have some limitations like plant spacing, height of plant, bushy structure of plant and cost of machine etc. Manual picking increases the cost of cultivation and time consuming operation. The availability of labour for clean picking is also a major problem. The machine picking not only reduces the cost of cultivation but also has less dependency on labour and takes less time to picking. The labour requirement for cotton picking is approximately 500 man h/ha. Hence, commercially available low cost handheld portable cotton pickers having two type of mechanisms *i. e.* chain and roller were evaluated and their performance was compared with manual picking. With the help of Analysis of Variance (ANOVA) statistical method was applied to observe the significance of results between cotton picking machines and manual picking. Labour required during manual picking is significantly lower than roller type cotton picker at 5 per cent level of significance. There was no significant difference in the picking rate among chain, roller and manual picking at 5 per cent level of significance. The percentage of trash content for both chain and roller type cotton pickers was higher i.e. 11.52 and 10.44 per cent as compared to trash content of 7.43 per cent measured for cotton picked manually.

Key words : Cotton varieties, Manual picking, Portable handheld chain type cotton picker, Portable handheld roller type cotton picker, trash analyzer

The cost of Cotton cultivation for various operations particularly manual picking has increased many folds. The availability of labour for clean picking is also a serious constraint. Amongst all the field operations in cotton, the labour requirement for cotton picking is 500 man h/ha. It is not only tedious work but also ten times costlier than cost of irrigation and about twice the cost of weeding operation (Prasad and Majumdar, 1999). A grown up person can pick about 15-20 kg/day of seed cotton, compared to average picks of 870-2180 kg/day by a single row spindle type picker (Sandhar, 1999). In the year 2010-2011, the manual pickers were charging Rs.5-7/kg in the Punjab state. On an average, picking cost is approximately 10 per cent of the total income from the crop. There has been a shortage of labour availability on cotton farms for manual picking results delayed picking.

The cotton is picked mostly manually in many countries. Once the cotton is picked (either mechanically or manually) it is transported to a cotton gin, where the cotton fibres (lint) are separated from the cottonseeds. Cotton varieties grown in countries like India and china are bushy type and tall growing. The holdings are also small and fragmented, high initial cost of cotton pickers and their high capacity made their use uneconomical.

Some device is needed to increase the efficiency of picking besides attracting people to the arduous task of hand picking of cotton. The need is particularly apparent at this time because of renewed interest by textile mills in obtaining cleaner higher quality cotton fibre. While minimizing the quantity of trash at harvest time, a hand operated machine was introduced recently to facilitate the manual labour for cotton harvesting. This manually operated mechanical cotton picker is simple in construction, light in weight and practically efficient in operation.

A handheld portable type cotton picking machines were evaluated in cotton field.

Field evaluation of handheld cotton picking machine: Commercially available portable hand held cotton pickers having two different mechanism *i.e.* chain type and roller type were evaluated in the Cotton field to check their performance and efficiency. Different varieties of cotton were selected for harvesting. The evaluations of these machines were carried out at Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana and Research Station, Punjab Agricultural University, Abohar on October-November 2011. The data in Table 1 showed plant characteristics for different cotton varieties sown in the field. Handheld cotton pickers were also evaluated for a LH2076 cotton variety which is bushy type grown in the region along with short dwarf varieties/hybrids like MRC6301, F2383 and MRC6304 which are considered suitable for mechanical harvesting. Two types of mechanism used for handheld cotton harvesting machine are explained below.

Table 1. Plant characteristics data of different cotton varieties

Sr. No.	Plant characteristics	Variety			
		MRC6301	F2383	MRC6304	LH2076
1	Plant height (cm)	56.40	73.60	98.10	149.0
2	Width along row (cm)	22.20	36.60	68.60	59.33
3	Width across row (cm)	22.20	42.30	58.40	60.00
4	Monopods/plant	1-2	0-1	1-2	2-3
5	Length of monopods (cm)	13.20	25.80	70.30	81.33
6	Sympods/plant	15-18	18-21	19-22	20-23
7	Height of lower most green boll (cm)	10.50	18.62	19.70	55.33
8	Height of upper most green boll (cm)	35.20	62.60	83.30	137.00

Chain type portable handheld cotton picking machine: The chain type portable handheld cotton picker consisted of a D.C. motor; belt-pulley arrangement and an endless chain as shown in Fig. 1.

Fig. 1. Pictorial view of chain type portable handheld cotton picker

Top and side views of chain type cotton picking machine are shown in Fig. 2.

D.C. motor of 12 volt having power 11 W is used to provide power to belt pulley arrangement. DC motor was operated with battery capacity 12V7AH/20HR, having charge time about 8 h with 5 h discharge time. The belt pulley arrangement was further attached with the chain sprocket mechanism of cotton picker to rotate it. The driver belt pulley was having 12 mm dia. and chains were rotated with the help of driven pulley of 50 mm dia. The chain of picker was attached with prickles which were actually removing the cotton from open boll. The metal wire, fixed over the chain was used as a doffer to separate the picked cotton from chain prickles. A separate bag was provided to be tied behind the operator for collection of the harvested cotton.

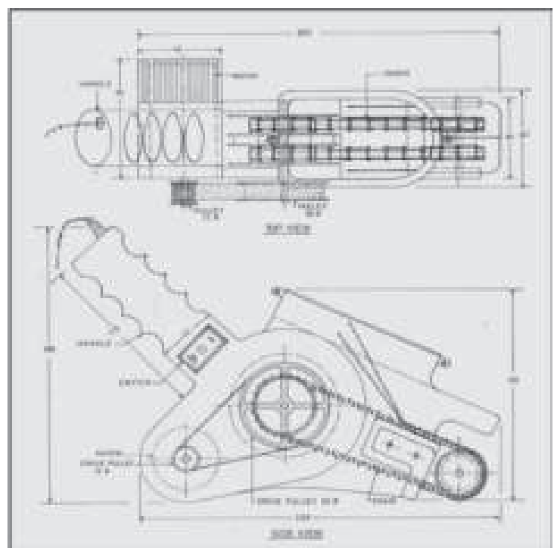

Fig. 2. Top and side view of chain type portable handheld cotton picker

Roller type portable handheld cotton picker: The roller type portable handheld cotton picker consisted of a D.C. motor, belt pulley arrangement and a cylindrical roller (Fig. 3). D.C.

motor of 12 volt having power 11 W is used to provide power to belt pulley arrangement. DC motor was operated with battery capacity 12V7AH/ 20HR. The driver belt pulley was directly attached with the cylindrical roller pulley, acting as a driven pulley to rotate the roller of cotton picker. The roller was mounted with prickles instead of prickles attach at the chain in chain type mechanism to remove the cotton from plant. The metal wire was used as a doffer to separate the picked cotton from prickles. A separate bag was provided to tie behind the operator for collection of cotton harvested by cotton picker. This machine can continuously work for a long time without any problem.

Fig. 3. Pictorial view of roller type portable handheld cotton picker

Operation of portable handheld cotton picker in field: Cotton collecting bag was attached with the portable cotton picker which was tied to the belly of the operator (Fig. 4). The cotton picking machine was operated manually with on/off switch button. The bag attached behind the operator with the picking machine was used to collect the harvested cotton. The operator has to put the harvesting side near the open bolls, the prickles mounted on the chain or roller will bring the cotton in the bag attached behind the operator.

Measurement of labour requirement and picking rate: Labour requirement for cotton picking was measured as total man h required to harvest one ha area of cotton field. For the measurement of labour requirement, two cotton strips of 30 x 1 m were selected to harvest with handheld cotton pickers and manually. Thus, total time consumed during the harvesting of selected strips with both cotton pickers and manual picking was measured to calculate the labour requirement (man h/ha) for different cotton varieties.

Picking rate (kg/hr) of seed cotton was measured by measuring the weight of seed cotton picked in the field. The weight of picked cotton was measured for both handheld cotton pickers and manual picking.

Fig. 4. Mounting of portable hand held cotton picker

Measurement of trash in laboratory : Cotton has a high affinity for everything with which it comes in contact. Hence, it is hardly possible to harvest cotton without trash. To measure the seed cotton trash, a commercially available Texaco trash analyzer made by Texaco Engineering was used. The equipment was used for separating the impurity contents from the harvested cotton. The equipment was used for

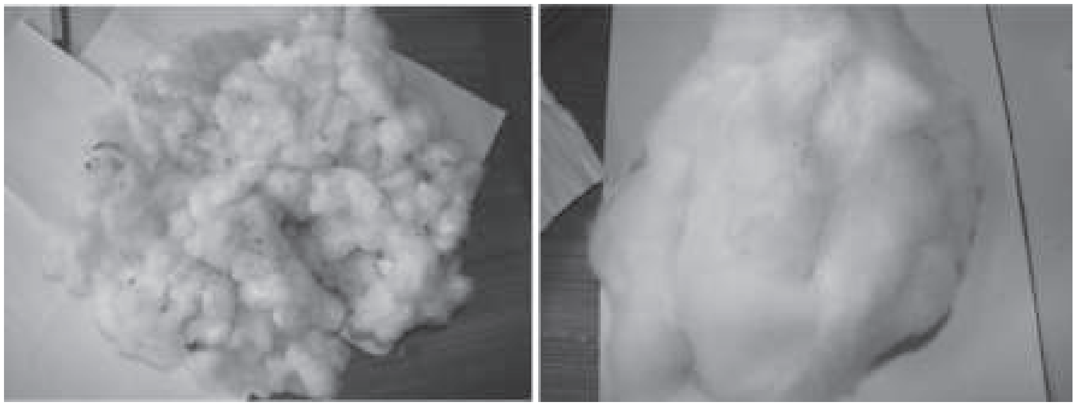

Fig. 5. Cotton sample before and after trash analyzing operation

the numerical weight proportional and percentage determination of solid impurities in natural fibrous material samples. The intensive opening and separating capacity of the equipment enable the test sample to be separated into components. Sample of Cotton fibrous material by separating cotton seed is prepared for analysis. The sample is fed into the equipment having articulated feeding claws, split feeder and opening, blades, using negative rake fixed opening cylinder, while the selection and separation are carried out, in mechanical way, by air blast splitter. Trash is to be weighed separately using an analytical balance (Fig. 5).

Statistical method: Analysis of variance (ANOVA) is used to observe the significance of results between handheld cotton picking machines and manual picking. It compared the variation between cotton picking machines and manual picking and within the cotton picking machines.

The results outcome of two portable cotton pickers *i.e.* chain type and roller type evaluated in the field has been discussed in this section.

Labour requirement: Potable hand held cotton pickers were evaluated for MRC6304, MRC6301, LH2076 and F2383 cotton varieties.

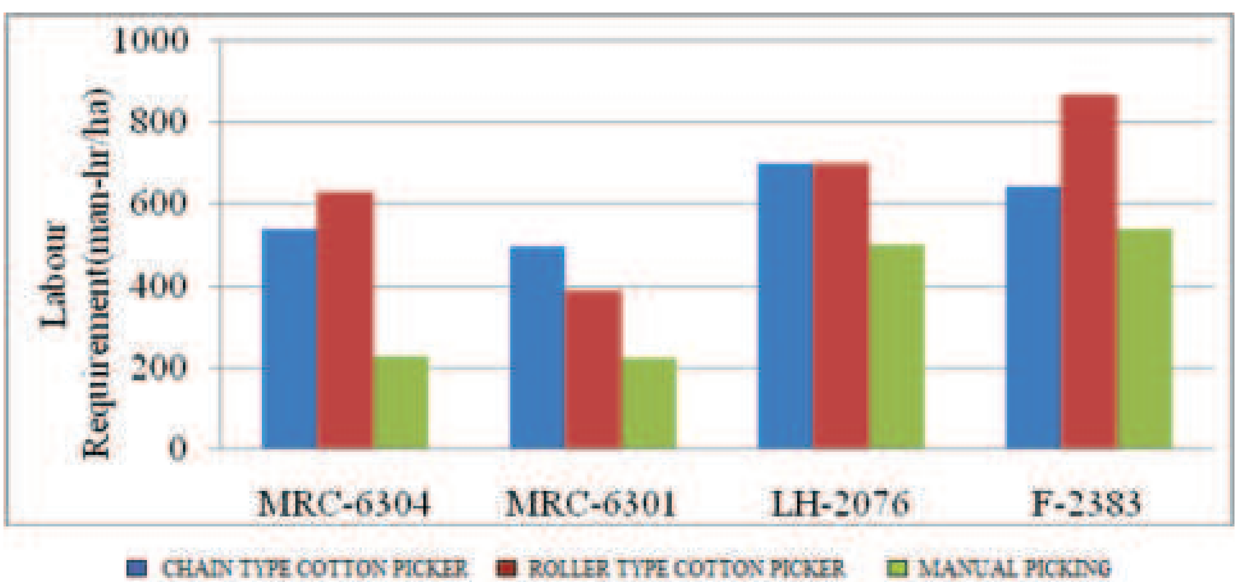

Fig. 6. Comparison of labour requirement among different cotton varieties

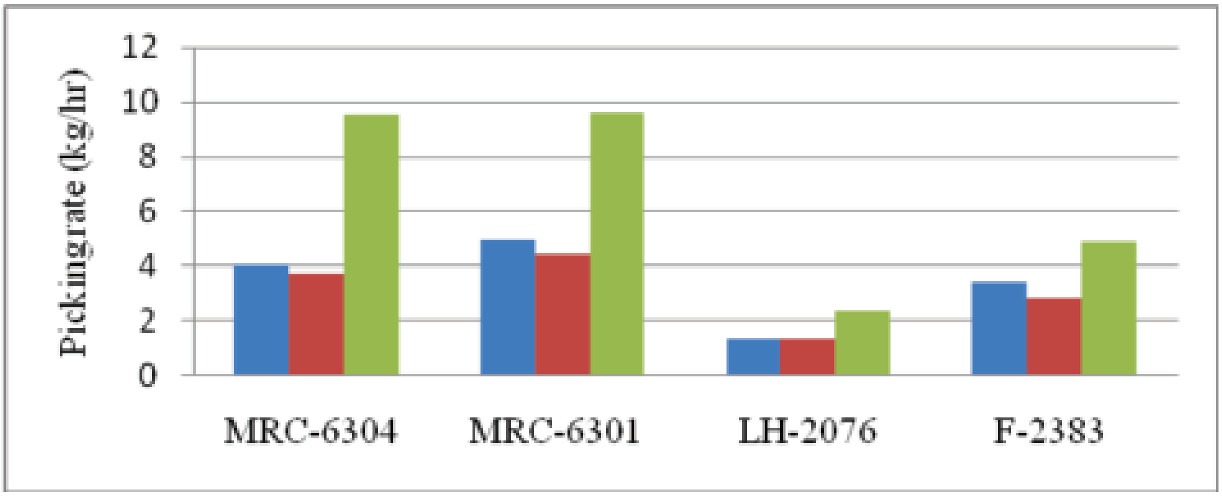

Fig. 7. Comparison of picking rate (kg/hr) for different varieties

Table 2. Comparison of average labour requirement (man-hr/ha), picking rate and trash content (grams) between portable handheld cotton pickers and manual picking for MRC6304, MRC6301, LH2076 and F2383 varieties

Sr. No.	Type of picking*		Labour requirement (man h/ha)	Picking rate (kg/h)	Trash content (g)
1	Portable handheld cotton pickers	Chain type	592.25	3.44	11.52
		Roller type	645.00	3.09	10.44
2	Manual picking		372.75	6.63	7.43

The labour required for picking machines and its comparison with labour required for manual picking of cotton is mentioned in Table 2. Fig. 6 showed the graphical representation of labour requirement between cotton picking machines and manual picking for different cotton varieties. It was observed that manual picking required lesser labour as compared to mechanical picking for all types of cotton varieties. However, labour required during manual picking of cotton is not significantly different than the labour required for chain type machine. But it is significantly lower than the roller type cotton picking machine at 5 per cent level of significance. Maximum labour *i.e.* 868 man h/ha were consumed for cotton variety F2383 during the cotton harvesting by roller type cotton picker and minimum labour *i.e.* 224 man h/ha were consumed for variety MRC6301, which was harvested manually. During the cotton harvesting with chain type cotton picker, maximum working h *i.e.* 699 h were consumed for LH2076 variety and minimum working h *i.e.* 493 h were consumed for MRC6301 variety. Similarly, for roller type cotton picker, maximum working h *i.e.* 868 h were consumed for F2328 variety and minimum time *i.e.* 385 h were consumed for harvesting MRC6301 variety. During the manual harvesting, maximum time *i.e.* 538 h were required for picking F2328 variety and minimum time *i.e.* 224 h were required for picking MRC6301variety. Labour required for harvesting MRC6301 variety is significantly different as compared to the labour required in variety F2383 for any type of picking. But it is not significantly different with MRC6304 and LH2076. our results are in accurdance with the findings of Ankit (2008).

Picking rate: Portable handheld cotton pickers were evaluated to measure the picking rate (kg/h) of harvested cotton for different cotton varieties. The weight of cotton harvested/unit time by cotton picking machines was compared to the weight of cotton picked manually. Table 2 showed the measured data of picking rate with cotton picking machines and manually. Fig. 7 is the graphical representation of picking rate (kg/h) between cotton picking machines and manual picking. There was significant difference of picking rate for variety MRC6301 and LH2076.

For all types of picking methods, picking rate was maximum for MRC6301 variety and it was minimum for LH2076 variety. It may be due to the reason that MRC6301 variety was fully matured but LH2076 variety which is bushy type, was having green bolls at the time of harvesting. There was no significant difference in the picking rate among chain type, roller type and manual picking at 5 per cent level of significance.

Trash analysis of harvested cotton: Data in Table 2 showed the trash analysis data for 100 g sample of cotton harvested with both handheld cotton pickers and manually. The weight of clean cotton and cotton seed were measured 29.61 and 58.87 g, respectively for chain type cotton picker. For the roller type cotton picker, the weight measured for clean cotton and cotton seed were 28.56 and 61.00 g, respectively. Similarly, for manual picking, the measured weight for clean cotton and cotton seed were 34.42 and 58.15 g, respectively. The percentage of trash content for both chain and roller type cotton pickers was high *i.e.* 11.52 and 10.44 per cent as compared to trash content of 7.43 per cent measured for cotton picked manually. Our results are in confirmity with the findings of Asota (19966).

- Labour required during manual picking is not significantly different than the labour required for chain type machine. Significantly lower than the roller type cotton picking machine at 5 per cent level of significance.
- For all types of picking methods, picking rate was maximum for MRC6301 and minimum for LH2076.
- There was no significant difference in the picking rate among chain type, roller type and manual picking at 5 per cent level of significance.
- The percentage of trash content for both chain and roller type cotton pickers was higher *i.e.* 11.52 and 10.44 percent as compared to trash content of 7.43 percent measured for cotton picked manually.

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Performance evaluation of self propelled walk behind power weeder in cotton crop

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ABSTRACT : A self propelled walk behind power weeder was evaluated for its performance and compared with manual weeding at farmer's field in Hisar district of Haryana state in *kharif,* 2010. Heart rate responses and overall discomfort ratings of power weeder were studied to quantify the drudgery involved in operation of this weeder. The field capacity of the power weeder was found to be 0.12 ha/h with field efficiency of 93 per cent. The weeding efficiency of the power weeder was found to be 65 per cent as compared to 96 per cent by manual weeding. The plant damage was 60 per cent less in power weeding than manual weeding. The fuel consumption was found to be 0.65 l/h or 5.42 l/ha. There were 95 per cent time and 82 per cent cost saving in weeding with power weeder as compared to manual weeding. The mean heart rate of the operator during power weeding was 118.7 beats/min and overall discomfort rating on the VAD scale was 3.8 for operating duration of 30 min as compared to 95 beats/min and discomfort rating of 3.4 in manual weeding. The payback period of the power weeder was less than one year.

Key words : Discomfort rating, hand hoe, heart rate, rotary power weeder, weeding efficiency

Cotton is the principal commercial crop of India. The area under cotton cultivation was 10.31 mha during 2009-2010 with the production of 30.50 mbales (Anonymous, 2012) having productivity of 502 kg/ha, which is very less as compared to world productivity of 760 kg/ha. The present demand for cotton is estimated to the tune of 40 mbales. Looking at the growth rate so far, this seems to be a difficult task, as any further increase in cotton area is a remote possibility. Mechanization can enhance the productivity by ensuring efficient resource utilization, timeliness of operation, decreasing inputs cost and increasing labour efficiency.

One of the main reasons for low productivity of cotton in India is the weed infestation as they compete for vital inputs (water, nutrients and sunlight) with main crop. Losses caused by weeds in cotton crop ranges from 40-45 per cent depending upon nature and intensity of weeds (Veerangouda *et al.*, 2010) and sometimes it can be as high as 80 - 90 per cent and can cause total crop failure. Weed control is one of the most expensive and labour intensive operation in crop production. In India, Rs. 4200 million is being lost annually due to weeds (Natarajan, 1987). On an average, the cost of weeding comes to Rs. 945/ha out of the total cost of cultivation of Rs. 3000/ ha for agricultural crops (Tajuddin *et al.*, 1991).

Indian farmers mainly follow mechanical weeding though chemical weeding is slowly becoming popular, inspite of its higher cost. The arduous operation of weeding is performed manually with the use of hand hoe (*Kasola*) in upright bending posture, inducing back pain for majority of labourers. Weeding by using hand hoe (*Kasola*) is labour intensive as 300 – 1200 man h/ha is required during entire crop (2-4 weeding) and labours are not easily available in peak seasons. Traditional methods are costly and time consuming. On the other hand, bullock drawn implements have certain draw backs like low field capacity, high maintenance cost, limitations of adverse weather conditions etc. and are therefore not affordable to the farmers. Tractor operated weeders can save 75 per cent time and 20 per cent cost as compared to bullock drawn weeder but there is more plant damage and wastage in head lands (Pachghare and Narkhede, 1999). Power tiller farming cost is about 44.4 and 11.4 per cent less than bullock and tractor farming, respectively but power tiller farming increases heart beat rate of the operator during interculture operation upto 140 beats/ min and overall discomfort rating for an operating duration of 30 min was found 4.5 on 10 point VAD scale (Narang and Tiwari, 2005). The cost of weeding by engine operated weeders comes to only one third of the weeding cost by manual labour (Tajuddin, 2006).

Keeping in view a study was carried out for performance evaluation and economic feasibility of power weeder and their comparison with manual weeding at farmer's field. Heart rate responses and overall discomfort ratings was also studied to quantify the drudgery involved in weeding operation.

A Light weight self propelled walk behind power weeder (Table 1) was evaluated for the present study at the farmer's field in district Hisar of Haryana state during *kharif,* 2010. The evaluation was carried out based on the weeding efficiency, plant damage, field capacity, field efficiency, fuel consumption, labour requirement and cost of operation. The performance of power weeder was compared with the performance of manual weeding by hand hoe (*Kasola*) on the basis of weeding efficiency, plant damage, time, labour and cost of operation. The soil type of the field was loamy sand and moisture content of the field at the time of interculture operation was 21.50 per cent (db). The operation was performed after 45 days of sowing of cotton crop. The average plant height at the time of operation was 40 cm. The average weed intensity before interculture operation was 9.45 g/m^2 and bulk density of the field soil was 1.5 g/m^3. The rotary speed of the weeder was measured by using a non contact type digital tachometer. The depth of operation was measured using a depth gauge. The cost of operation for power weeder was worked out by straight line method.

To assess the drudgery involved during the rotary tilling operation for interculture, heart rate responses and overall comfort ratings were studied during operation of power weeder. The trials of 30 min duration were conducted and replicated thrice. Heart rate was measured by using a heart rate monitor (Polar NV) and overall discomfort rating was assessed using a 10 point visual analogue discomfort scale (VAD) where zero was anchored as no discomfort and 10 as extreme discomfort. Average temperature and relative humidity during intercultural operation in cotton crop varied from 35 – 40^{o} C and 30 – 35 per cent, respectively.

Data on various field performance parameters during interculture operation in cotton crop is given in Table 2. The average field capacity of the power weeder was 0.12 ha/h at a forward speed of 1.8 km/h with the field efficiency of 93 per cent. The working depth varied from 40 to 65 mm depending upon soil moisture content, with an average value of 54 mm at a soil moisture content of 21.50 per cent (db). The average fuel consumption of power weeder was 0.65 l/h or 5.42 l/ha. The weeds in the strip of land covered by the rotary unit were completely uprooted. However, the power weeder could not be operated close to the plants and an average distance of 125 mm was left on both sides to avoid the damage to the plants. This was mainly because of poor balancing of the power weeder, which results in zigzag movement. Thus the overall weeding efficiency of power weeder was 65 as compared to 96 per cent in manual weeding. The plant damage in power weeding was 1.6 as compared to 4 per cent in manual weeding. Similar results were found by Kathirwal *et al.*, 2007. Plant damage was higher in manual weeding as the manual labour tries to cover the entire space between rows. The time required to cover one ha was 8.33 h with power weeder which was 95 per cent less than manual weeding with hand hoe (*Kasola*). Pannu *et al.*, 2002 also confirm these results.

The mean heart rate during rotary power weeding was 118.7 beats/min, therefore, the physiological workload during operation was under the category of heavy work (110 to 130 beats/min.) (Astrand and Rodhal, 1977). The overall discomfort rating on the 10 point visual analogue discomfort scale for the operating duration of 30 min was 3.8. The heart rate values

Table 1. Technical specifications of power weeder

Particulars	Values
Type	Self propelled walk behind
Manufacturer	Amar Agricultural Works Ltd., Ludhiana, Punjab
Engine	4.8 HP Diesel Engine (Greaves Ltd.)
Engine RPM	1500
Dimensions (mm)	1740 x 600 x 1100
Working width (mm)	450
Number of blades	16
Diameter of rotary unit (mm)	300
Material of blade	High carbon steel
Cost (Rs.)	70000/-

Table 2. Comparative field performance of power weeder and manual hand hoe (*Kasola*)

S. No.	Particulars	Values	
		Power Weeder	Manual hand hoe (*Kasola*)
1	Average soil moisture content (%) (db)	21.50	21.50
2	Average speed of operation (km/h)	1.80	-
3	Effective field capacity (ha/h)	0.12	0.0063
4	Field efficiency (%)	93	-
5	Average depth of tilling (mm)	54	54
6	Width of operation (mm)	45	70
7	Weeding efficiency (%)	65	96
8	Plant damage (%)	1.6	4
9	Fuel consumption (l/h)	0.65	-
10	Fuel consumption (l/ha)	5.42	-
11	Cost of operation (Rs/h)	135	40
12	Cost of operation (Rs/ha)	1125	6360
13	Mean heart rate (beats/min)	118.7	95
14	Overall discomfort rating on 10 point VAD scale	3.8	3.4
15	Cost saving (%)	82	-
16	Time saving (%)	95	-
17	Pay back period (Year)	1	-

during operation exceeded the allowable limit of 110 beats/min for 8 h work by Indian workers (Saha *et al.*, 1979). The high values of heart rate was primarily due to heavy workload posed by poor balancing of the weeder, which requires continuous effort by the operator to move the power tiller in straight line. The mean heart rate during manual weeding was 95 beats/min which was under the allowable limit of 110 beats/min. The overall discomfort rating on the 10 point visual analogue discomfort scale for the operating duration of 30 min was almost equal (3.4) as in manual weeding the worker is always in bending position.

The cost of weeding with power weeder was Rs. 950/ha, which is only 27 per cent of the weeding cost by manual labour (Rs. 2800/ha). There was a net saving of Rs. 5400/ha (3 weedings), as was also confirmed by Pannu *et al.*, 2002. The payback period of the self propelled walk behind power weeder was one year only.

CONCLUSIONS

Field capacity of the self propelled walk behind rotary power weeder was 0.12 ha/h with an efficiency of 93 per cent. The weeding efficiency of the weeder was found to be 65 per cent as compared to 96 per cent in manual weeding. The plant damage was 60 per cent less in rotary power weeding than manual weeding. There was 82 percent cost and 95 per cent time saving in power weeding as compared to manual weeding. The mean heart rate of the operator during power weeding was 118.7 beats/min as compared to 95 beats/min in manual weeding. Overall discomfort rating on the VAD scale was almost equal in both the methods. Payback period of the weeder was less than one year only.

Weeding with self propelled walk behind power weeder in cotton crop was time, labour and cost saving as compared to manual weeding but drudgery involved in rotary power weeding is slightly more which is quite acceptable.

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Effect of *Bt* cotton on survival and development of pink bollworm, *Pectinophora gossypiella* (Saunders)

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ABSTRACT : The mortality of early larval instars of *Pectinophora gossypiella* (Saunders) was higher than the later instars fed on bolls of 130 days old crop compared to those fed on bolls of 150 days old crop for all the *Bt* event hybrids. Exposure of later instar larvae to plant parts of *Bt* event hybrids exhibited adverse effects on the growth and development such as reduced larval weights, prolonged larval developmental period, reduced pupation, formation of small pupae with less weight, reduction in adult emergence with low growth and survival indices of *P. gossypiella*.

Key words : *Bt* cotton, development, events, *Pectinophora gossypiella*, survival

Cotton is one of the most ancient and important commercial fibre in India accounts for 65 per cent of the lint used in textile industry. In India the bollworms commonly encountered in cotton cultivation are Spotted bollworm, *Earias vittella* (Fabricius), American bollworm, *Helicoverpa armigera* (Hubner), Tobacco cutworm, *Spodoptera litura* (Fabricius) and the pink bollworm *Pectinophora gossypiella* (Saunders). Among these pink bollworm, *P. gossypiella* was to be one of the most serious pests of cotton worldwide causing losses in both yield and quality of cotton. Recently the *Bt* gene does not allow the development of bollworm population because of its inherent toxicity of the *Bt* cotton against bollworms (Kranthi *et al*., 2000). This has led to minimum usage of insecticides and is considered as one of the best tools of integrated pest management against bollworm complex. *Bt* genotypes proved eco friendly in the management of bollworm complex (Romeis *et al*., 2006). However, the present studies were conducted on the effect of Bt gene on the development of *P. gossypiella* as the insect was developed on cotton in the recent tome.

MATERIALS AND METHODS

In the present studies bioassay *Pectinophora gossypiella* (Saunders) was conducted with RCH 2 *Bt*, JK Durga *Bt*, Nath baba *Bt* and RCH 2 BGII *Bt* and their corresponding non *Bt* hybrids against *P.gossypiella* during *kharif*, 2007-2008 and 2008-2009 at Regional Agricultural Research Station, Guntur. To conduct the study the comparative development of all the larval instars *i.e.,* from second to fifth instars the larvae were on leaves and squares of different transgenic *Bt* event hybrids and their corresponding non *Bt* versions as control.

First instar larvae were collected from the damaged fruiting bodies of non *Bt* cotton and were reared on natural fresh fruiting parts in the laboratory. From the culture, first instar larvae of pink bollworm were separated out and released on cut opened *Bt* events and their corresponding non *Bt* hybrids with small amount of lint. For each treatment, 3 replications were maintained with 10 larvae/replication and were kept in petridishes at room temperature in laboratory. Similarly all other instars were bioassayed with the above procedure.

During each observation fresh bolls were provided for the surviving larvae. The weight of surviving larvae and pupal was recorded after 24, 48 and 72 h of exposure. The effect of treatments on larval mortality, larval development and pupation adult emergence were recorded separately. The growth and survival indices were calculated for different treatments.

Growth index = Per cent pupation/ Larval development period (days)

Survival index = Number of moths emerged/ Total number of neonates used

For adult maintenance the pupae of *P. gossypiella* was transferred to a glass jar and for emergence of adults. Freshly emerged male and female adults were transferred to a glass jar and the top of which was covered with muslin cloth with the help of rubber band. A small cotton swab dipped in 10 per cent honey solution was hung by means of a thread in the glass jar to facilitate feeding of adult moths and fresh food was provided every day by changing the swab. The data obtained were transformed appropriately and put to statistical analysis in Completely Randomized Block Design to test the level of significance (Rahaman and Goud, 2007).

RESULTS AND DISCUSSION

The data on mortality of all the five instars of *P. gossypiella* larvae were studied individually by exposing to bolls of 130 and 150 days old RCH 2 BGII, RCH 2 *Bt*, JK Durga *Bt* and Nath baba *Bt* hybrids and their corresponding non *Bt* hybrids. In addition other parameters *viz.,* pupa, weight of larvae and pupae, adult emergence and survival indices were observed from the surviving larvae and the results are presented in Table 1

Mortality of different larval instars of *P.gossypiella* reared on bolls of different cotton hybrids at130 and 150 DAS. At 130 DAS the mortality of 1st instar larvae was 100.00 per cent in *Bt* events of RCH 2 *Bt*, JK Durga *Bt*, Nath baba *Bt* and RCH 2 BGII hybrids and was less than 20.00 per cent on all other non *Bt* hybrids. Gradually the mortality of *P.gossypiella* decreased with advancement in the age of the larvae. The mortality of II instar was highest (71.66%) on RCH 2 BGII followed by RCH 2 *Bt* (70.00 %), JK Durga *Bt* (68.33%) and Nath baba *Bt* (66.66%) hybrids. The present findings are in conformity with Henneberry *et al.,* (2004). Recorded less than 8.33 per cent mortality of II instar larvae and was *on par* with each other. However, there was no mortality of *P.gossypiella* larvae of III, IV and V instar, when fed on non *Bt* hybrids. RCH 2 BGII with 51.66 per cent mortality of III instar larvae fed on bolls of 130 days old crop is significantly superior over other hybrids. The other *Bt* hybrids was recrded less than 50.00 per cent mortality in III instar larve. All most similar trend in larval mortality was observed on both *Bt* and non *Bt* hybrids during IV instar .There was no mortality on both *Bt* and non *Bt* hybrids during V instar.

The mortality of larvae fed on *Bt* hybrids on bolls of 150 days old was observed only upto IV instar larvae and it decreased with advancement of in the age of the larvae. The mortality of I instar larvae was only 80.00 per cent on RCH 2 BGII and was statistically *on par* with RCH 2 *Bt* (73.33%) and JK Durga *Bt* (73.33%) hybrids compared to 11.66 to 16.66 per cent larval mortality on non *Bt* hybrids. The mortality of II instar larvae fed on bolls of 150 days plant was 63.33 per cent in RCH 2 BGII hybrid and it was significantly more over the other hybrids. The other *Bt* hybrids were statistically on par and

Table 1. Per cent mortality of larval instars of *P.gossypiella* on test hybrids

Treatments	130 DAS				150 DAS			
	I instar	II instar	III instar	IV instar	I instar	II instar	III instar	IV instar
RCH 2 *Bt*	100	70	45	40	73.33	43.33	33.33	26.66
	(90.00)a	(76.78)b	(42.13)b	(39.23)b	(58.92)ab	(41.16)b	(35.25)b	(31.00)b
RCH 2 non *Bt*	20	8.33	0	0	11.66	3.33	0	0
	(26.45)b	(16.59)d	(0.00)d	(0.00)d	(19.88)c	(6.14)c	(0.00)d	(0.00)d
JK Durga *Bt*	100	68.33	41.66	38.33	73.33	41.66	31.66	20
	(90.00)a	(59.76)c	(40.19)c	(38.24)bc	(58.92)bc	(40.19)b	(34.23)bc	(26.56)c
JK Durga non *Bt*	18.33	6.66	0	0	16.66	6.66	0	0
	(25.30)b	(12.29)d	(0.00)d	(0.00)d	(23.85)c	(12.29)c	(0.00)d	(0.00)d
Nath baba *Bt*	100	66.66	41.66	36.66	70	40	26.66	23.33
	(90.00)a	(54.74)c	(40.19)c	(37.25)c	(56.83)b	(39.14)b	(31.00)c	(28.85)b
Nath baba non *Bt*	18.33	8.33	0	0	15	8.33	0	0
	(25.30)b	(16.59)d	(0.00)d	(0.00)d	(22.78)d	(13.74)c	(0.00)d	(0.00)d
RCH 2 BGII	100	71.66	51.66	43.33	80	63.33	50	38.33
	(90.00)a	(57.85)a	(52.95)a	(52.16)a	(63.54)a	(52.74)a	(45.00)a	(38.24)a
F TEST	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SEm±	1.03	1.52	0.63	0.64	1.66	4.45	1.17	0.71-
P=0.05	3.14	4.63	1.91	1.94	5.04	13.5	3.57	2.17-

Figures in parentheses are angular transformed values
Numbers followed by same superscript are not statistically different

significantly different from non *Bt* hybrids. The RCH 2 BGII hybrid recorded 50.00 per cent mortality of III instar larvae and it was significantly higher over the other hybrids .The mortality of III instar larvae was 33.33, 31.66 and 26.66 per cent when fed on RCH 2 *Bt*, JK Durga *Bt* and Nath baba *Bt* hybrids, respectively and are statistically *on par* with each other. Cent per cent survival of III, IV and V instar larvae were observed on all the non *Bt* hybrids. The mortality of IV instar larvae was 38.33 per cent on RCH 2 BGII hybrid and it is significantly superior over RCH 2 *Bt (*26.66%), Nath baba *Bt* (23.33%) and JK Durga *Bt* (20.00%). However, the mortality was nil in V instar was not noticed in both *Bt* and non *Bt* hybrids.

The mortality was higher at 130 days when compared to 150 days due to decline in Cry1Ac content as the age of the crop advances (Kranthi *et al*., 2005).The present finds also corroborate the reports of who reported higher mortality of pink bollworm larvae when fed on *Bt* cotton. Reported 42.60 per cent mortality of pink bollworm larvae fed on *Bt* cotton bolls for four days. *Bt* cotton technology has a capability of reducing insect pest infestations by 60-90 per cent under field conditions (Henneberry *et al*., 2004)).Toxins from *Bacillus thuringiensis* (*Bt*) are widely used for pest control. In particular, *Bt* toxin Cry lAc produced by transgenic cotton kills some key lepidopteran pests (Fabrick and Tabashnik, 2007).

The data pertaining to the mean weight of larvae that survived beyond 24, 48 and 72 h after exposure on bolls of 130 and 150 days old crop from all the seven test hybrids was recorded for II, III and IV instars (Table 2). The first generation of transgenic cotton with *B. thuringiensis* produces a single toxin, Cry1Ac, that is highly effective against susceptible larvae of pink bollworm (*P. gossypiella*), (Tabashnik *et al.,* 2002).

At 130 DAS crop the weight of II instar at 24 h after feeding was 5.53 mg on RCH 2 BGII hybrid and it was significantly lower compared other hybrids. The larval weight gain was maximum on non *Bt* hybrids compared to *Bt* hybrids in non *Bt* hybrids ranged between 56.00 to 58.00 per cent while in *Bt* range between 23.66 to 31.27 per cent of weight gain. The cumulative larval weight at 72 h after feeding was between 7.16 to 8.93 mg and 11.33 to 12.46 mg on *Bt* and non *Bt* hybrids, respectively. The RCH 2 BGII hybrid was least palatable to *P.gossypiella* as the larval weight at 72 h after feeding was very low (7.16 mg) compared to other *Bt* and non *Bt* hybrids. The pink boll worm larvae reared on bolls of 130 days *Bt* hybrids resulted in less weight at the end of 72 h after feeding compared to non *Bt* hybrids. The weight gain after 72 h of II instars larvae was lowest (30.16 %) on RCH 2 BGII and it is significantly superior over the other *Bt* and non *Bt* hybrids. The III instar larvae fed on RCH 2 BGII hybrid on bolls of 130 days crop showed the lowest larval weight at 24 h (11.60 mg), 48 h (12.66 mg) and 72 h (13.40 mg) after feeding. This hybrid was significantly superior over other test hybrids. The second best hybrid was RCH 2 *Bt* with less larval weight at 24 h (12.06 mg), 48 h (13.20 mg) and 72 h (14.66 mg) of feeding and it was superior to other hybrids. At 72 h after exposure of III instar the minimum per cent weight gain (17.91%) was observed on RCH 2 BGII followed by on RCH 2 *Bt* (24.96%), JK Durga *Bt* (29.95%) and Nath baba *Bt* (29.16%) hybrids. The per cent weight gain of III instar larvae was comparatively more was on non *Bt* hybrids *viz.,* Nath baba non *Bt* (42.10%), JK Durga non *Bt* (40.17%) and RCH 2 non *Bt* (40.00%). The IV instar larvae fed on bolls of RCH 2 BGII hybrid showed the lowest larval weight at 24 h (21.20 mg), 48 h (21.73 mg) and 72 h (23.30 mg) after feeding and it is significantly superior over the other hybrids. The mean weight of IV instar larvae was maximum on Nath baba non *Bt* hybrid at 24 h (24.60 mg), at 48 h (25.86 mg) and at 72 h (27.80 mg) after feeding. The per cent weight gain after 72 h was highest (24.46%) on Nath baba non *Bt* hybrid followed by RCH 2 non *Bt* (23.16%) and JK Durga non *Bt* (22.60%) hybrid. The per cent weight gain of IV instar larvae was lowest on RCH 2 BGII (9.87%) and RCH 2 *Bt* (13.93%) hybrids.

At 150 DAS the growth of larvae fed on RCH 2 BGII bolls of 150 days old was minimum and it was superior over the other hybrids tested in having less preference for feeding by *P.gossypiella* during all the three instars (Table: 3).The maximum mean weight II instar larvae of *P.gossypiella* was recorded on RCH 2 non *Bt* hybrid (9.40 mg) at 24 h after feeding. On other non *Bt* hybrids the mean weight ranged from 9.13 to 8.96 mg/larvae. The weight of *P.gossypiella* II

Table 2. Effect of test hybrid bolls of 130 DAS on *P.gossypiella* larval weight

Treatments	Mean weight (mg/larva) of II instar after			Weight gain (%)	Mean weight (mg/larva) of III instar after			Weight gain (%)	Mean weight (mg/larva) of IV instar after			Weight gain (%)
	24h	48h	72h		24h	48h	72h		24h	48h	72h	
RCH 2 *Bt*	5.93 (2.53)^{b}	7.06 (2.75)^{b}	8.46 (2.99)^{b}	40.9 (39.75)^{b}	12.06 (3.54)^{b}	13.2 (3.70)^{b}	14.66 (3.86)^{b}	24.96 (29.97)^{b}	22.46 (4.79)^{b}	23.86 (4.93)^{b}	24.4 (4.98)^{b}	13.93 (21.90)^{b}
RCH 2 non *Bt*	7.13 (2.76)^{d}	9.6 (3.17)^{d}	11.33 (3.43)^{d}	55.86 (48.36)^{b}	13.53 (3.74)^{d}	16.2 (4.08)^{d}	18.33 (4.33)^{d}	40 (39.23)^{e}	24 (4.94)^{c}	25.33 (5.08)^{c}	27.33 (5.27)^{d}	23.16 (28.76)^{d}
JK Durga *Bt*	6.26 (2.60)^{bc}	7.4 (2.81)^{bc}	8.8 (3.04)^{b}	43.18 (41.07)^{c}	12.73 (3.63)^{c}	13.73 (3.7)^{c}	15.06 (3.94)^{c}	26.95 (31.27)^{c}	22.2 (4.76)^{b}	23.93 (4.94)^{b}	24.93 (5.04)^{bc}	15.76 (23.38)^{c}
JK Durga non *Bt*	7.33 (2.79)^{d}	9.26 (3.12)^{d}	12.26 (3.57)^{e}	59.21 (50.30)^{e}	13.8 (3.78)^{de}	17.33 (4.32)^{e}	18.4 (4.34)^{d}	40.17 (39.33)^{e}	24.53 (5.00)^{d}	25.8 (5.12)^{cd}	27.13 (5.25)^{d}	22.6 (28.37)^{d}
Nath baba *Bt*	6.53 (2.65)^{c}	7.6 (2.84)^{c}	8.93 (3.07)^{c}	44 (41.55)^{e}	13 (3.64)^{c}	13.93 (3.79)^{c}	15.53 (4.00)^{c}	29.16 (32.68)^{d}	22.53 (4.80)^{b}	23.93 (4.94)^{b}	25.2 (5.06)^{c}	16.66 (24.08)^{c}
Nath baba non *Bt*	7.4 (2.81)^{d}	9.13 (3.10)^{d}	12.46 (3.60)^{e}	60 (50.76)^{e}	13.86 (3.79)^{e}	17.73 (4.29)^{e}	19 (4.41)^{e}	42.1 (40.45)^{f}	24.6 (5.01)^{d}	25.86 (5.13)^{d}	27.8 (5.31)^{d}	24.46 (29.63)^{d}
RCH 2 BGII	5.53 (2.45)^{a}	6.6 (2.66)^{a}	7.16 (2.76)^{a}	30.16 (33.30)^{a}	11.6 (3.49)^{a}	12.66 (3.62)^{a}	13.4 (3.72)^{a}	17.91 (25.03)^{a}	21.2 (4.65)^{a}	21.73 (4.71)^{a}	23.3 (4.86)^{a}	9.87 (18.29)^{a}
F TEST	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SEm±	0.01	0.01	0.01	0.33	0.01	0.01	0.02	0.36	0.01	0.01	0.02	0.45
P=0.05	0.07	0.08	0.05	1.02	0.04	0.05	0.06	1.1	0.05	0.04	0.06	1.36
Initial weight	5	—	—	—	11	—	—	—	21	—	—	—

Figures in parentheses are square root transformed values
Numbers followed by same superscript are not statistically different

instar was lowest on RCH 2 BGII (6.60 mg) at 24 h after exposure and it is statistically *on par* with RCH 2 *Bt* (6.93 mg). The maximum mean weight of *P.gossypiella* II instar larvae was recorded fed on bolls of RCH 2 BGII hybrid at 48 h (7.13 mg) and at 72 h (7.86 mg) after exposure and it is significantly superior over the other hybrids. The highest mean larval weight was noticed in II instar after 48 (11.93 mg) and 72 h (13.93 mg) feeding on Nath baba non *Bt* hybrid. The per cent weight gain in II instar larvae was minimum on RCH 2 BGII (23.66%) followed by RCH 2 *Bt* (31.27%) ,JK Durga *Bt* (33.77%) and Nath baba *Bt* (37.53%) hybrid at 72 h after exposure. Nath baba non *Bt* (15.60 mg) was the most preferable host by III instar larvae followed JK Durga non *Bt* (14.60 mg) and RCH 2 non *Bt* (14.53 mg) hybrids at 24 h after feeding. The lowest larval weight was observed on RCH 2 BGII at 24 h (12.66 mg), 48 h (13.46 mg) and 72 h (14.60 mg) of feeding during III instar. The maximum larval weight (20.46 mg) was observed in RCH 2 non *Bt* hybrid after 72 h of feeding during III instar. The minimum weight gain (17.80%) was recorded on RCH 2 BGII while the maximum weight gain (41.34%) was recorded in RCH 2 non *Bt* hybrid at 72 h after exposure of III instar larvae. The larval weight of IV instar at 24 h after exposure on 150 days old bolls was lowest (22.60 mg) on RCH 2 BGII and RCH 2 *Bt* (23.20 mg) and both were *on par* with each other and significantly superior to all other hybrids. The maximum weight (25.66 mg) at 24 h after exposure was recorded in Nath baba non *Bt* during IV instar. At 48 h after exposure the weight of IV instar larvae on RCH 2 BGII hybrid was lowest (23.26 mg) and significantly superior over the other hybrids. RCH 2 *Bt* (24.06 mg), JK Durga *Bt* (24.60 mg) and Nath baba *Bt* (25.26 mg) hybrid are superior over the their corresponding non *Bt* hybrids *viz*, RCH 2 non *Bt* (28.06 mg), JK Durga non *Bt* (28.66 mg) and Nath baba non *Bt* (28.00 mg). The minimum mean larval weight of IV instar at 72 h after exposure was recorded in RCH 2 BGII hybrid (24.13 mg) and it was significantly superior over the other test hybrids. The highest weight of IV instar larvae of *P.gossypiella* was observed in JK Durga non *Bt* hybrid (30.46 mg) but it is *at par* with RCH 2 non *Bt* (30.13 mg) and Nath baba non *Bt* (30.00 mg). The minimum per cent weight gain (10.07%) was recorded in RCH 2 BGII hybrid and it is significantly superior over other hybrids. The maximum weight gain (27.77%) was recorded in JK Durga non *Bt* hybrid at 72 h after exposure.

The data pertaining to the pupation of pink bollworm at 130 DAS.The first instar larvae fed, on bolls of 130 days old crop of RCH 2 *Bt*, JK Durga *Bt*, Nath baba *Bt* and RCH 2 BGII hybrids, failed to reach the pual stage. However about 80.00 per cent of first instar larvae fed on non *Bt* hybrids reached pupal stage (Table: 5). Some larvae of II, III and IV instar fed on *Bt* hybrid bolls of 130 days old survived upto the end of the larval stage and reached pupal stage. The pupation of II instar larvae was lowest (28.33%) on RCH 2 BGII hybrid followed by RCH 2 *Bt* (30.00%), JK Durga *Bt* (31.67%) and Nath baba *Bt* (33.34%) hybrids, but were significantly different from their corresponding non *Bt* hybrids which recorded 91.67 to 93.33 per cent pupation . The per cent pupation of III and IV instar larvae fed on *Bt* hybrids was in the range of 48.33 (RCH 2 BG II) to 58.33 (JK Durga Bt and Nath baba *Bt*) and 56.67 (RCH BG II) to 63.33 (Nath baba *Bt*), respectively as against cent per cent in non *Bt* hybrids. In case of V instar larvae fed on both *Bt* hybrids and non *Bt* hybrids, cent per cent pupation was observed

At 150 DAS the per cent pupation of I and II instar larvae fed on 150 day old bolls of *Bt* hybrids varied from 20.00 (RCH 2 BGII) to 30.00 (Nath baba *Bt*) and 36.67 (RCH 2 BGII) to 60.00 per cent (Nath baba *Bt*) respectively . In case of non *Bt* hybrids the per cent pupation of I and II instar ranged from 83.33 (RCH 2 non *Bt*) to 85.00 (Nath baba non *Bt*) and 81.67 (JK Durga non *Bt*) to 96.67 pre cent (RCH 2 *Bt*), respectively. The Pupation of III instar larvae fed on bolls was lowest (50.00%) on RCH 2 BGII followed by RCH 2 *Bt* (66.67%), JK Durga *Bt* (68.33%) and Nath baba *Bt* (73.33%) hybrids as against 100.00 per cent pupation on non *Bt* hybrids. Similar trend in pupation was noticed during IV instar. The per cent pupation of V instar larvae was cent per cent both *Bt* and non *Bt* hybrids.

The mean pupal weight of *P.gossypiella* larvae on different test hybrids .None of the I instar larvae fed on 130 days old bolls of *Bt* hybrids *viz.* RCH 2 *Bt*, JK Durga *Bt*, Nath baba *Bt* and RCH 2 BGII were able to reach pupal stage (Table 4). The pupal weight of II, III, IV and V instars larvae fed on bolls of 130 days old *Bt* hybrids was less compared to their corresponding non *Bt* hybrids.

Table 3. Effect of test hybrid bolls of 150 DAS on *P.gossypiella* larval weight

Treatments	Mean weight (mg/larva) of II instar after			Weight gain (%)	Mean weight (mg/larva) of III instar after			Weight gain (%)	Mean weight (mg/larva) of IV instar after			Weight gain (%)
	24h	48h	72h		24h	48h	72h		24h	48h	72h	
RCH 2 *Bt*	6.93	7.86	8.73	31.27	13.2	14.46	15.2	21.05	23.2	24.06	25.4	13.38
	(2.72)^{ab}	(2.89)^{b}	(3.03)^{b}	(33.00)^{b}	(3.70)^{b}	(3.86)^{b}	(3.96)^{b}	(27.30)^{b}	(4.86)^{ab}	(4.95)^{b}	(5.08)^{b}	(21.44)^{b}
RCH 2 non *Bt*	9.4	11	12.73	58.86	14.53	16.73	20.46	41.34	25.53	28.06	30.13	27
	(3.14)^{e}	(3.39)^{d}	(3.63)^{d}	(46.63)^{e}	(3.87)^{d}	(4.15)^{c}	(4.57)^{e}	(40.01)^{e}	(5.10)^{de}	(5.34)^{d}	(5.53)^{c}	(31.30)^{d}
JK Durga *Bt*	7.13	8.2	9.06	33.77	13.73	14.66	15.8	24.05	23.86	24.6	25.73	15
	(2.76)^{b}	(2.94)^{b}	(3.09)^{b}	(35.52)^{c}	(3.77)^{c}	(3.89)^{b}	(4.03)^{c}	(29.36)^{c}	(4.93)^{bc}	(5.00)^{bc}	(5.12)^{b}	(22.77)^{b}
JK Durga non *Bt*	9.13	11.26	13.53	55.65	14.6	17	19.73	39.17	25.26	28.66	30.46	27.77
	(3.10)^{de}	(3.43)^{d}	(3.74)^{e}	(48.24)^{f}	(3.88)^{d}	(4.18)^{c}	(4.49)^{d}	(38.74)^{d}	(5.07)^{cd}	(5.40)^{d}	(5.56)^{c}	(31.80)^{d}
Nath baba *Bt*	7.53	8.66	9.6	37.53	13.33	14.86	15.86	24.33	23.6	25.26	25.93	15.15
	(2.83)^{c}	(3.02)^{c}	(3.17)^{c}	(37.77)^{d}	(3.71)^{bc}	(3.92)^{b}	(4.04)^{c}	(29.55)^{c}	(4.90)^{b}	(5.07)^{c}	(5.14)^{b}	(22.90)^{c}
Nath baba non *Bt*	8.96	11.93	13.93	56.92	15.6	16.53	19.6	38.77	25.66	28	30	26.66
	(3.07)^{d}	(3.52)^{e}	(3.79)^{e}	(48.97)^{f}	(4.01)^{e}	(4.12)^{c}	(4.48)^{d}	(38.50)^{d}	(5.11)^{e}	(5.33)^{d}	(5.52)^{c}	(31.08)^{d}
RCH 2 BGII	6.6	7.13	7.86	23.66	12.66	13.46	14.6	17.8	22.6	23.26	24.13	10.07
	(2.66)^{a}	(2.76)^{a}	(2.89)^{a}	(29.10)^{a}	(3.62)^{a}	(3.73)^{a}	(3.60)^{a}	(24.94)^{a}	(4.80)^{a}	(4.87)^{a}	(4.96)^{a}	(18.48)^{a}
F TEST	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SEm±	0.02	0.01	0.02	0.35	0.02	0.02	0.02	0.38	0.03	0.02	0.02	0.44
P=0.05	0.06	0.05	0.06	1.07	0.06	0.07	0.06	1.15	0.09	0.07	0.06	1.35
Initial weight	6	—	—	—	12	—	—	—	22	—	—	—

Figures in parentheses are square root transformed value
Numbers followed by same superscript are not statistically different

The pupae formed from larvae of II instar fed on RCH 2 BGII (14.86 mg) was less in weight followed by RCH 2 *Bt* (17.66 mg), JK Durga *Bt* (18.33 mg) and Nath baba *Bt* (18.53 mg) compared to those formed on Nath baba non *Bt* (25.80 mg), JK Durga non *Bt* (25.40 mg) and RCH 2 non *Bt* (24.73 mg). The minimum pupal weight of III instar was observed on RCH 2 BGII (15.20 mg) followed by RCH 2 *Bt* (17.80 mg), JK Durga *Bt* (18.70 mg) and Nath baba *Bt* (19.00 mg) hybrids. The highest pupal weight of III instar was observed on RCH 2 non *Bt* (25.06 mg) hybrid followed by JK Durga non *Bt* (24.73 mg) and Nath baba non *Bt* (24.46 mg). Significantly lowest pupal weight of IV instar (15.60 mg) and V instar (22.46 mg) was recorded on RCH 2 BGII compared to other *Bt* hybrids and their corresponding non *Bt* hybrids .However, the pupal weight of V instar larvae fed on RCH 2 *Bt*, JK Durga *Bt* and Nath baba *Bt* was lower and was *on par* with each other compared to non *Bt* hybrids.

At 150 DAS the weight of pupae formed from first instar (17.06 mg) II (19.06 mg), III (19.40 mg, IV (20.60 mg) and V (21.66 mg) instar larvae fed on RCH 2 BGII was significantly lower compared to that formed on other *Bt* hybrids and their corresponding non *Bt* hybrids. The pupal weight varied from 20.10 to 20.68 mg on all the *Bt* hybrids and it is significantly lower than the pupal weight on their corresponding non *Bt* hybrids in I instar (22.33-22.86 mg). Similar trend was observed in pupal weight of *Bt* hybrids (21.00-21.2-53 mg; 21.73-22.16 mg) and non *Bt* (23.13-23.20 mg; 23.06 to 23.20 mg) hybrids fed to II and III instar larvae. However, significant difference was not noticed in pupal weights of *Bt* hybrids (23.53-23.86 mg) and non *Bt* hybrids (23.66-23.93 mg) fed to IV instar larvae. On the other hand, the pupal weight of V instar larva fed with *Bt* hybrids varied from 22.60 to 23.13 mg and non *Bt* hybrids from 24.00 to 24.06 mg.

The first instar reared on bolls 130 of days old *Bt* hybrids failed to reach adult stage, contrary to about 80.00 per cent adult emergence on non *Bt* hybrids (Table 6). The adult emergence from II instar larvae fed with *Bt* hybrids ranged from 3.33 to 10.00 per cent and was significantly lower than their corresponding non *Bt* hybrids (91.66-93.33%). On the other hand, the adult emergence from III (10.00 to 30.00%) and IV (30.00- 43.30%) instar larvae reared on *Bt* hybrids was significantly lower than that non *Bt* hybrids .However ,adult emergence from V instar larvae reared on both *Bt* and non *Bt* hybrids was cent per cent.

The adult emergence of I instar larvae reared on bolls of 150 day old *Bt* hybrids was low (6.66-13.33%) compared to II (10.00-23.33.%) and III (16.66-36.66%) instars .The lowest adult emergence was recorded from II instar larvae

Table 4. Per cent pupation of surviving larvae of *P.gossypiella* on test hybrids

Treatments	130 DAS				150 DAS			
	I instar	II instar	III instar	IV instar	I instar	II instar	III instar	IV instar
RCH 2 *Bt*	0 (0.00)[a]	30 (33.21)[a]	55 (47.87)[b]	60 (50.85)[a]	26.67 (31.00)[ab]	56.67 (48.84)[b]	66.67 (54.78)[b]	73.33 (59.00)[b]
RCH 2 non *Bt*	80 (63.43)[b]	91.67 (73.40)[c]	100 (90.00)[c]	100 (90.00)[b]	83.33 (70.11)[c]	96.67 (93.95)[d]	100 (90.00)[c]	100 (90.00)[d]
JK Durga *Bt*	0 (0.00)[a]	31.67 (34.23)[ab]	58.33 (49.80)[b]	61.67 (51.75)[a]	26.67 (31.00)[ab]	58.33 (49.80)[b]	68.33 (55.76)[b]	80 (63.43)[c]
JK Durga non *Bt*	81.67 (64.70)[b]	93.33 (77.71)[d]	100 (90.00)[c]	100 (90.00)[b]	83.33 (66.14)[c]	81.67 (64.69)[c]	100 (90.00)[c]	100 (90.00)[d]
Nath baba *Bt*	0 (0.00)[a]	33.34 (36.23)[b]	58.33 (49.80)[b]	63.33 (52.74)[a]	30 (33.21)[b]	60 (50.85)[b]	73.33 (59.00)[b]	76.66 (61.21)[bc]
Nath baba non *Bt*	81.67 (64.69)[b]	91.67 (73.40)[c]	100 (90.00)[c]	100 (90.00)[b]	85 (67.40)[c]	91.67 (73.40)[c]	100 (90.00)[c]	100 (90.00)[d]
RCH 2 BGII	0 (0.00)[a]	28.33 (32.14)[a]	48.33 (44.04)[a]	56.67 (48.84)[a]	20 (26.56)[a]	36.67 (37.22)[a]	50 (45.00)[a]	61.67 (51.75)[a]
F TEST	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SEm±	0.67	2.67	0.9	1.56	1.88	3	1.73	1.24
P=0.05	2.04	2.5	2.7	4.75	5.7	9.09	5.26	3.76

Figures in parentheses are angular transformed values
Numbers followed by same superscript are not statistically different

Table 5. Mean weight (mg) of Pupae from surviving larvae of *P.gossypiella* on test hybrids

Treatments	130 DAS					150 DAS				
	I instar	II instar	III instar	IV instar	V instar	I instar	II instar	III instar	IV instar	V instar
RCH 2 *Bt*	0	17.66	17.8	17.86	24.13	20.33	21	21.73	23.53	22.6
	(0.00)^{a}	(4.26)^{b}	(4.24)^{b}	(4.28)^{b}	(4.96)^{bcd}	(4.56)^{b}	(4.63)^{b}	(4.71)^{b}	(4.90)^{b}	(4.80)^{b}
RCH 2 non *Bt*	24.2	24.73	25.06	25.33	24.8	22.33	23.13	23.06	23.66	24
	(4.96)^{c}	(5.02)^{d}	(5.05)^{e}	(5.08)^{e}	(5.02)^{cd}	(4.79)^{c}	(4.86)^{c}	(4.85)^{d}	(4.91)^{b}	(4.94)^{c}
JK Durga *Bt*	0	18.33	18.7	19.06	23.8	20.68	21.4	21.73	23.66	22.66
	(0.00)^{a}	(4.33)^{bc}	(4.38)^{c}	(4.42)^{c}	(4.92)^{b}	(4.60)^{b}	(4.67)^{b}	(4.71)^{b}	(4.91)^{b}	(4.81)^{b}
JK Durga non *Bt*	23.86	25.4	24.73	24.66	25.06	22.8	23.2	23.2	23.93	24.06
	(4.93)^{c}	(5.06)^{de}	(5.02)^{de}	(4.97)^{d}	(5.05)^{d}	(4.82)^{c}	(4.86)^{c}	(4.86)^{d}	(4.94)^{b}	(4.95)^{c}
Nath baba *Bt*	0	18.53	19	19.53	23.93	20.1	21.53	22.16	23.86	23.13
	(0.00)^{a}	(4.36)^{c}	(4.41)^{c}	(4.47)^{c}	(4.94)^{bc}	(4.53)^{b}	(4.69)^{b}	(4.76)^{bc}	(4.93)^{b}	(4.86)^{b}
Nath baba non *Bt*	23.33	25.8	24.46	24.93	24.86	22.86	23.06	22.83	23.93	24.03
	(4.88)^{b}	(5.12)^{e}	(4.99)^{d}	(5.04)^{de}	(5.03)^{cd}	(4.83)^{c}	(4.85)^{c}	(4.83)^{cd}	(4.94)^{b}	(4.95)
RCH 2 BG-II	0	14.86	15.2	15.6	22.46	17.06	19.06	19.4	20.6	21.66
	(0.00)^{a}	(3.91)^{a}	(3.96)^{a}	(4.01)^{a}	(4.79)^{a}	(4.19)^{a}	(4.42)^{a}	(4.46)^{a}	(4.59)^{a}	(4.70)^{a}
F TEST	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SEm±	0.01	0.02	0.01	0.03	0.03	0.03	0.02	0.02	0.02	0.02
P=0.05	0.03	0.07	0.05	0.1	0.09	0.1	0.07	0.08	0.06	0.06

Figures in parentheses are square root transformed values
Numbers followed by same superscript are not statistically different

fed on RCH 2 BGII (10.00%) and it was statistically *on par* with RCH 2 *Bt* (16.66%) and JK Durga *Bt* (20.00%) hybrids. The highest adult emergence ranging from 81.66 to 96.66 per cent was noticed in case of II instar larvae fed on non *Bt* hybrids. The adult emergence from III instar larvae was lowest on RCH 2 BGII (16.66%) followed by RCH 2 *Bt* (26.66%), JK Durga *Bt* (30.00%) and Nath baba *Bt* (36.66%) compared to cent per cent emergence on non *Bt* hybrids.

The growth index values for *P.gossypiella* larvae reared on bolls of 130 days old crop were 1.93 on RCH 2 BG II, 2.26 on RCH 2 *Bt*, 2.43 on JK Durga *B*, 2.53 on Nath baba *Bt* hybrid as against 8.11, 8.33 and 8.33 on corresponding non *Bt* hybrids, respectively (Table 7). On 150 days old crop the growth index values were 2.08 on RCH 2 BG II, 3.22 on RCH 2 *Bt*, 3.41 on JK Durga *Bt* and

Table 6. Per cent adult emergence of *P.gossypiella* on test hybrids

Treatments	130 DAS				150 DAS			
	I instar	II instar	III instar	IV instar	I instar	II instar	III instar	IV instar
RCH 2 *Bt*	0	10	20	36.66	10	16.66	26.66	36.66
	(0.00)^{a}	(18.43)^{a}	(26.56)^{b}	(37.22)^{b}	(18.43)^{a}	(23.85)^{ab}	(31.00)^{b}	(37.22)^{b}
RCH 2 non *Bt*	80	91.66	100	100	88.33	96.66	100	100
	(63.43)^{b}	(73.40)^{b}	(90.00)^{d}	(90.00)^{d}	(70.11)^{b}	(83.85)^{e}	(90.00)^{d}	(90.00)^{d}
JK Durga *Bt*	0	10	23.33	40	10	20	30	43.33
	(0.00)^{a}	(18.43)^{a}	(28.78)^{b}	(39.23)^{bc}	(18.43)^{a}	(26.56)^{ab}	(33.21)^{bc}	(41.15)^{bc}
JK Durga non *Bt*	81.66	93.33	100	100	83.33	81.66	100	100
	(64.69)^{b}	(77.71)^{b}	(90.00)^{d}	(90.00)^{d}	(66.14)^{b}	(64.69)^{c}	(90.00)^{d}	(90.00)^{d}
Nath baba *Bt*	0	6.66	30	43.33	13.33	23.33	36.66	50
	(0.00)^{a}	(12.29)^{a}	(33.21)^{c}	(41.15)^{c}	(21.14)^{a}	(28.78)^{b}	(37.22)^{c}	(45.00)^{c}
Nath baba non *Bt*	81.66	91.66	100	100	85	91.66	100	100
	(64.69)^{b}	(73.40)^{b}	(90.00)^{d}	(90.00)^{d}	(67.40)^{b}	(73.40)^{d}	(90.00)^{d}	(90.00)^{d}
RCH 2 BGII	0	3.33	10	30	6.66	10	16.66	23.33
	(0.00)^{a}	(6.14)^{a}	(18.43)^{a}	(33.21)^{a}	(12.29)^{a}	(18.43)^{a}	(23.85)^{a}	(28.78)^{a}
F TEST	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
SEm±	0.67	4.14	0.83	1.05	2.92	2.8	1.52	1.34
P=0.05	2.04	12.56	2.53	3.18	8.9	8.5	4.62	4.07

Figures in parentheses are angular transformed values
Numbers followed by same superscript are not statistically different

Table 7. Growth and survival indices for P.gossypiella on test hybrids

Test hybrids	Growth index (DAS)		Survival index (DAS)	
	130	150	130	150
RCH 2*Bt*	2.26	3.22	0.2	0.26
RCH 2 non *Bt*	8.11	8.33	1	1
JK Durga *Bt*	2.43	3.41	0.23	0.3
JK Durga non *Bt*	8.33	8.33	1	1
Nath baba *Bt*	2.53	3.79	0.3	0.36
Nath baba non *Bt*	8.33	8.33	1	1
RCH2 BG II	1.93	2.08	0.1	0.16

3.79 on Nath baba *Bt* hybrid as against 8.33 on non *Bt* hybrids.

The survival index values for *P.gossypiella* larvae reared on bolls of 130 days old crop were 0.10 on RCH 2 BG II, 0.20 on RCH 2 *Bt*, 0.23 on JK Durga *Bt* and 0.30 on Nath baba *Bt* hybrid as against 1.00 on RCH 2 non *Bt*, JK Durga non *Bt* and Nath baba non *Bt.* On 150 days old crop the growth index values were 0.16 on RCH 2 BG II, 0.26 on RCH 2 *Bt*, 0.30 on JK Durga *Bt*, 0.36 on Nath baba *Bt* as against 1.00 on RCH 2 non *Bt*, JK Durga non *Bt* and Nath baba non *Bt*. The data pertaining to the growth and survival indices indicated that the growth index values were significantly low for the larvae reared on bolls of 130 days old crop compared to those reared on 150 days old *Bt* event hybrids. Among the *Bt* event hybrids the growth and survival indices were significantly low in RCH 2 BGII hybrid as compared to non *Bt* hybrids.

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Population dynamics and management of mealybug in cotton

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ABSTRACT : Experiment was carried out during *kharif* , 2008 and 2009 at CCS Haryana Agricultural University, Hisar with 19 genotypes comprising of 17 *Bt* hybrids, 1 conventional hybrid and one variety under unsprayed conditions. The population of mealybug varied among *Bt* and non *Bt* genotypes and was higher in non *Bt* genotypes. Maximum population was recorded in 35th and 34th standard week of 2008 and 2009, respectively. Mean maximum population was recorded in H 1226 (0.84 in 2008 and 0.07/plant on grade basis in 2009), respectively. Low intensity of mealybug was observed during 2009 due to presence of its natural enemy *i.e. Aenasius bambawalei* Hayat. Mealybug population was positively correlated with temperature, sunshine h and wind speed while negatively correlated with rainfall and relative humidity. Profenophos 50 EC @ 5 ml/L of water and *neem* oil (1500 ppm) + nirma powder (0.1%) were found effective in managing mealybug population.

Key words : Abiotic factors, *Bt* cotton, damage potential, mealybug, pesticides

Mealybugs (Hemiptera: Pseudococcidae) are small oval, soft-bodied, cottony in appearance and covered with white mealy wax. It is a polyphagous pest on several weeds like *Parthenium hysterophorus, Xanthium strumarium, Acyranthes aspera, Tribulus terrestris, Abutilon indicum, Trianthema portulacastrum, Chenopodium murale,* etc. and found sucking on leaves, stems and roots of the plants (Vennila *et al.*, 2010). During 2007 solenopsis mealybug, *Phenacoccus solenopsis* appeared in serious form in cotton growing areas of India namely Punjab, Haryana, Rajasthan, Maharashtra and Gujarat and caused widespread damage to cotton crop and farmers had to ploughed up their badly infested cotton fields at many places.

It is very difficult to manage mealybug population by the insecticides alone since insecticides may not penetrate its body due to waxy coating over the dorsal body surface. More over, its often involves the caretaking ants without these, the small and slow moving mealybugs can't invade new areas.

MATERIALS AND METHODS

The experiments trials were conducted at CCS Haryana Agricultural University, Hisar during *kharif,* 2008 and 2009 under unsprayed conditions with 19 genotypes comprising of 17 *Bt* hybrids, one conventional hybrid and 1 variety. Sowing of RCH 134 was done on 25th May, 2008 and 15th of May, 2009 in a randomized block design (RBD) with three replications in a plot size of 24.3 m^2 each. The observations for mealybug were recorded on randomly selected 5 plants / plot at weekly interval on grade basis and infestation was assessed as per protocol. Observations were recorded before spraying the insecticides and 7 and 10 days after application after tagging 10 plants from each treatment. The different treatments of bio-pesticides and synthetic insecticides were applied to know the reactions against the infestation intensities of mealybug (Table 1). The insecticides were applied at the boll formation stage of the crop. Damage potential was worked out by comparing the yield data of various treatments with the untreated control.

Mealybug infestation was graded as under :

0 = No mealybug
1 = Few mealybugs seen on any of the twig of the plant considering as 10 per cent damage
2 = One branch infested heavily with mealybugs considering as 25 per cent damage
3 = Two or more branches infested heavily with mealybugs, up to 50 per cent plant affected
4 = Completely affected considering as 100 per cent damage

RESULTS AND DISCUSSION

Data presented in Table 2 and 3 indicated that under unsprayed conditions the population of mealybug varied among *Bt* and non-*Bt* genotypes, being higher in non *Bt* genotypes. During 2008 mealybug appeared in 33rd week on

Table 1. Details of insecticides for the control of cotton mealybug (*Phenacoccus solenopsis*)

Insecticides used	Dosage
Profenophos 50 EC	5 ml/L
NSKE (5%)	2 ml/L
Neem oil 1500 ppm + *nirma* powder (0.1%)	—
Nirma powder (0.1%)	1g/L
Verticilium lecanii (2x10^8 cfu/mg)	2 g/L
Beauveria bassiana (2x10^8 cfu/mg)	2 g/L
Metarhizium anisopliae (2x10^8 cfu/mg)	2 g/L
Fish oil rosin soap	2 ml/L
Untreated control (water spray)	—

H 1226 irrespective of genotypes and maximum population was recorded in 35th standard week. It ranged from 0.0 to 2.00 mealybugs/plant on grade basis. Mean minimum population on ANKUR JASSI BG II (0.28 grade/plant). Mean maximum population was recorded H 1226 (0.84 grade/plant) (Table 2). During 2009, low intensity of mealybug was observed due to presence of its natural enemy *i.e. Aenasius bambawalei* Hayat. However, the higher population was recorded in 34th standard week. Amongst the genotypes, no infestation could be recorded on KDCHH 441 BG II, NCS 913 *Bt* and IT 905 *Bt,* whereas mean minimum population was recorded on VBCH 1501 BG II (0.01 grade/plant) while mean maximum population was recorded in H 1226 (0.07grade/plant) (Table 3).

Fig. 1. Mealy bug (*Phenacoccus solenopsis*) population on cotton plant

Mealybug population was significantly positively correlated with temperature sunshine and wind speed while negatively correlated with rainfall and relative humidity (Table 4). However, Jeyakumar *et al.,* (2009) reported that *P.*

Table 2. Population of cotton mealy bug in *Bt* and non-*Bt* genotypes of cotton during 2008 crop season

Genotypes	Mealybug population* in different standard weeks								**Mean**
	33	34	35	36	37	38	39	40	
KDCHH 9810 BG I	0.00	0.66	1.00	0.66	0.33	0.07	0.20	0.44	**0.42**
KDCHH 441 BG II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
TULSI 45 BG II	0.00	0.66	1.00	0.11	0.33	0.07	0.27	0.55	**0.37**
MRC 7031 BG II	0.00	0.89	1.00	0.22	0.55	0.13	0.13	0.66	**0.45**
MRC 6301 *Bt*	0.00	1.00	1.66	0.53	0.66	0.13	0.13	0.89	**0.63**
RCH 134 BG II	0.00	0.89	1.44	0.33	0.22	0.00	0.27	0.66	**0.48**
RCH 134 *Bt*	0.07	0.89	1.00	0.00	0.44	0.20	0.07	0.44	**0.39**
VBCH 1504 BG II	0.00	0.66	1.00	0.33	0.11	0.13	0.13	0.22	**0.32**
VBCH 1501 BG II	0.00	0.66	0.89	0.55	0.33	0.00	0.20	0.53	**0.39**
VBCH 1006 *Bt*	0.00	0.89	1.00	0.55	0.55	0.00	0.00	0.66	**0.46**
SIGMA *Bt*	0.00	1.00	1.22	0.22	0.66	0.13	0.13	0.89	**0.53**
ANKUR 2534 *Bt*	0.00	1.00	1.00	1.11	1.00	0.00	0.13	0.77	**0.63**
ANKUR JASSI BG II	0.00	0.55	0.89	0.33	0.22	0.00	0.00	0.22	**0.28**
NCS 145 *Bt* II	0.00	1.00	1.33	0.22	0.33	0.00	0.20	0.66	**0.47**
NCS 913 *Bt*	0.00	1.00	1.33	0.53	0.22	0.13	0.27	0.53	**0.50**
NCEH 6 *Bt*	0.00	1.33	1.55	0.89	0.66	0.13	0.13	1.00	**0.71**
IT 905 *Bt*	0.00	1.00	1.00	0.53	0.66	0.13	0.27	0.53	**0.52**
HHH 223 (LC)	0.00	1.33	1.66	0.55	0.89	0.13	0.27	1.00	**0.73**
H 1226 (LC)	0.13	1.66	2.00	0.53	0.66	0.33	0.40	1.00	**0.84**
Mean	**0.01**	**0.90**	**1.16**	**0.43**	**0.46**	**0.09**	**0.17**	**0.61**	**0.48**

*Per plant population on grade basis

Table 3. Population of cotton mealy bug in *Bt* and non-*Bt* genotypes of cotton during 2009 crop season

Genotypes	Mealy bug population* in different standard weeks								**Mean**
	33	34	35	36	37	38	39	40	
KDCHH 9810 BG I	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**
KDCHH 441 BG II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
TULSI 45 BG II	0.00	0.13	0.00	0.13	0.00	0.07	0.13	0.07	**0.06**
MRC 7031 BG II	0.00	0.07	0.13	0.00	0.07	0.00	0.07	0.13	**0.04**
MRC 6301 *Bt*	0.00	0.07	0.00	0.07	0.00	0.00	0.00	0.00	**0.02**
RCH 134 BG II	0.00	0.13	0.07	0.00	0.00	0.7	0.13	0.07	**0.05**
RCH 134 *Bt*	0.00	0.07	0.00	0.07	0.07	0.00	0.00	0.13	**0.04**
VBCH 1504 BG II	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.07	**0.03**
VBCH 1501 BG II	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	**0.01**
VBCH 1006 *Bt*	0.00	0.07	0.13	0.00	0.00	0.07	0.00	0.00	**0.05**
SIGMA *Bt*	0.00	0.13	0.00	0.07	0.00	0.07	0.13	0.00	**0.05**
ANKUR 2534 *Bt*	0.00	0.07	0.07	0.07	0.00	0.00	0.00	0.00	**0.04**
ANKUR JASSI BG II	0.00	0.00	0.13	0.00	0.00	0.07	0.13	0.00	**0.03**
NCS 145 *Bt* II	0.00	0.07	0.13	0.07	0.00	0.07	0.07	0.07	**0.06**
NCS-913 *Bt*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
NCEH 6 *Bt*	0.00	0.07	0.13	0.07	0.00	0.07	0.13	0.00	**0.06**
IT 905 *Bt*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
HHH 223 (LC)	0.00	0.07	0.00	0.13	0.00	0.13	0.07	0.00	**0.06**
H 1226 (LC)	0.00	0.07	0.13	0.13	0.00	0.07	0.07	0.00	**0.07**
Mean	**0.00**	**0.06**	**0.05**	**0.04**	**0.01**	**0.04**	**0.05**	**0.03**	**0.03**

*Per plant population on grade basis

Table 4. Correlation coefficient (r) of mealybug population with abiotic factors

Weather parameters	Mealybug population/plant		
	2008	2009	**Pooled**
Temperature (°C)			
Maximum	0.76**	0.30*	**0.57****
Minimum	0.49**	-0.26*	**0.31***
Average	0.77**	0.03	**0.45****
Relative humidity (%)			
Morning	-0.49**	0.01	**-0.25**
Evening	-0.29*	-0.47**	**-0.05**
Average	-0.37**	-0.36**	**-0.13**
Other factors			
Sunshine hours	0.43**	0.78**	**0.40****
Rainfall (mm)	-0.51**	-0.37**	**-0.04**
Wind speed(Km/h)	0.12	-0.29*	**0.34****

*Significant at 5% **Significant at 1%

solenopsis incidence and intensity were negatively correlated with maximum and minimum temperature. *P. solenopsis* population has been reported by several workers to be positively correlated with the maximum temperature and negatively correlated with the rainfall (Suresh and Kavitha, 2008; Dhawan *et al.,* 2009; Hanchinal *et al.*, 2010).

Suresh *et al.,* (2010) studied seasonal incidence of *P. solenopsis* on cotton. Maximum population of the pest (35 mealybugs/5cm) was observed during June and that decreased slowly during September and there was no incidence up to February, the present findings are in

Table 5. Efficacy of insecticides against mealybug, *Phenacoccus solenopsis*, on infestation and seed cotton yield during 2008 and 2009 crop season

Name of insecticides/ biopesticides	Doses	Mean yield of seed cotton (q/ha)*			
		2008	2009	Increase over untreated control (%) 2008	Increase over untreated control (%) 2009
Profenophos 50EC	5 ml/L	24.60	26.52	**26.54**	**29.56**
Fish oil cosin soap	2ml/L	20.13	21.73	10.23	12.94
Metarhizium anisopliae (2x10^8 cfu/mg)	2 g/L	21.49	23.46	15.91	24.68
Beauveria bassiana (2x10^8 cfu/mg)	2 g/L	22.33	22.69	19.07	19.42
Verticillium lecanii (2x10^8 cfu/mg)	2 g/L	20.79	21.55	13.08	17.00
Nirma Powder (1%)	1 g/L	22.06	22.89	18.08	15.98
NSKE (5%)	2 ml/L	21.93	22.66	17.6	17.29
Neem oil 1500 ppm + *nirma* powder (0.1%)		23.33	24.17	**22.54**	**24.80**
Untreated control (water spray)		18.07	19.31		

Table 6. Evaluation of insecticides and bio-pesticides for management of mealy bug during 2008 and 2009 crop season

S. No.	Name of the insecticides/ biopesticides	Doses	Mean mealy bug infestation (%) during 2008						Reduction after both sprays (%)	Mean mealy bug infestation (%) during 2009						Reduction after both sprays (%)
			28-8-2008 Before Spray		1/9/2008 After I[st] Spray		13-9-2008 After II[nd] spray			2/9/2009 Before Spray		5/9/2009 After I[st] Spray		17-9-2009 After II[nd] spray		
1	Profenophos 50EC	5 ml/L	80.31	-63.72	51.32	-45.75	28.46	-32.18	**48.13**	47.4	-43.43	26.64	-29	11.17	-20.26	**36.22**
2	Fish oil rosin soap	2ml/L	72.5	-58.35	59.59	-50.51	46.54	-42.94	25.96	45.3	-42.29	32.39	-34.67	19.34	-25.16	25.3
3	*Metarhizium anisopliae* (2x10^8 cfu/mg)	2 g/L	81.76	-68.96	63.85	-53.43	47.47	-43.53	34.29	54.56	-47.76	36.65	-36.99	20.27	-26.71	34.3
4	*Beauveria bassiana* (2x10^8 cfu/mg)	2 g/L	67.14	-55.38	51.89	-46.12	35.78	-36.61	41.36	39.94	-39.03	24.69	-29.1	9.5	-16.77	30.44
5	*Verticillium Lecanii* (2x10^8 cfu/mg)	2 g/L	70.6	-57.55	58.76	-50.09	35.72	-36.67	34.88	41.29	-39.47	30.03	-32.69	11.07	-17.53	30.22
6	*Nirma* powder (1%)	1 g/L	77.46	-66.59	50.57	-45.31	38.37	-38.26	39.09	50.26	-45.08	23.37	-28.79	19.77	-24.93	30.49
7	NSKE (5%)	2 ml/L	74.6	-60.64	53.84	-47.5	38.37	-38.22	36.23	34.6	-31.22	18.89	-25.27	7.87	-15.07	26.73
8	*Neem* oil 1500 ppm + *nirma* powder (0.1%)		61.8	-52.75	40.08	-38.79	24.13	-28.93	**47.67**	43.4	-41.1	31.56	-33.92	8.52	-16.15	**34.88**
9	Untreated control (water spray)		60.56	-56.46	75.13	-65.03	81.71	-68.94		33.36	-33.81	47.93	-43.73	54.51	-47.89	
	CD (p= 0.05)			(NS)		(NS)		-12.41			(NS)		(NS)		-13.89	
	SE (m) ±			-8.82		-6.45		-4.01			-7.74		-5.79		-4.59	

Figures below in column at no. 1 are mean of three replications
Figures below in column at no. 2 are angular transformed values

accordance with these findings. The results are not in conformity with Hanchinal *et al.,* (2010) who reported the population *P. solenopsis* ranged from 0.50-180.42 mealybugs on 10 cm top apical shoot length during 38th to 14th meteorological week.

Data presented in Table 5 revealed that during both the crop seasons (2008 and 2009) maximum per cent increase of yield over untreated control was observed in profenophos 50EC (5ml/l) treated plots *i.e.* 26.54 in 2008 and 29.56 per cent during 2009 followed by *neem* oil 1500 ppm + *nirma* powder (0.1%) *i.e.* 22.54 and 24.8 per cent during 2008 and 2009, respectively. Acephate, chlorpyriphos, fish oil rosin soap and detergent powder have been reported to record higher yield over untreated control.

Data presented in Table 6 revealed that among the pesticides evaluated for the management of mealybug, profenophos and *neem* oil (1500 ppm) + *nirma* powder (0.1%) were found equally effective. During 2008, 48.13 per cent reduction of mealybug was observed after two sprays of profenophos 50EC while 47.67 per cent reduction in *neem* oil (1500 ppm) + *nirma* powder (0.1%). Minimum reduction of mealybug was observed in fish oil rosin soap (25.96%). During 2009, 36.22 per cent reduction was observed in profenophos 50EC and 34.88 per cent reduction in *neem* oil (1500 ppm) + *nirma powder* (0.1%). Minimum reduction was observed in Fish oil rosin soap (25.30%).

Dhawan *et al*., (2009) and Aggarwal *et al*., (2009) who reported that profenophos 50 EC at 1250 ml /ha was more effective against *P. solenopsis* on cotton than chlorpyriphos and carbaryl. Jhala *et al.,* (2010) reported that profenophos proved to be most effective with 90.66 per cent reduction in mealybug population.

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Influence of weather parameters on the incidence of major bollworms on *Bt* and non *Bt* cotton hybrids

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ABSTRACT : The studies on seasonal dynamics of bollworms on *Bt* cotton hybrids indicated that the larval incidence of American bollworm, *Helicoverpa armigera* (Hubner) and pink bollworm, *Pectinophora gossypiella* Saunders was very low on *Bt* versions compared to their non *Bt* versions and the initiation of incidence was delayed by 2-3 weeks on *Bt* versions. The *Bt* genotypes had no adverse effects on egg laying of *H.armigera*. The correlation analysis revealed that there was highly significant positive correlation between the occurrence of *H.armigera* eggs and evening relative humidity (r = 0.599 to 0.684) in all the hybrids. While, significant positive association was observed between larval incidence of both *H.armigera* and *P.gossypiella* and morning relative humidity and evening relative humidity in non *Bt*'s and check hybrid. In addition, minimum temperature showed significant negative influence on the larval incidence of pink bollworm in MECH 12 non *Bt* (r= -0.687), RCH 2 non *Bt* (r = -0.685) and Bunny (r = -0.675) hybrids.

Key words : Bollworms, *Bt* cotton, correlation, regression, weather parameters

India has the largest area under cotton cultivation in the world, but the productivity is low because of higher insect pest damage at all the stages of crop growth. About 184 insect pests have been recorded on cotton in India which causes 30-80 per cent loss to yield and among them, bollworm complex was considered as the major constraint. The development of transgenic cotton cultivars incorporated with Cry 1 Ac gene helped the farmers to manage the resistant population of the bollworm, *Helicoverpa armigera* (Hubner) and resulted in an immense increase in the seed cotton yield and reduction in the insecticidal sprays from 3.10 to 1.17. But, the first generation *Bt* cotton cultivars can control the bollworms upto 100 to110 days only and thereafter the toxin expression declined gradually and is inadequate to control bollworms (Greenplate, 1999).

MATERIALS AND METHODS

The studies on seasonal incidence of American bollworm and pink bollworm were carried out at RARS, Lam, Guntur during *kharif*, 2004-2005 and 2005-2006. Two *Bt* hybrids *viz.,* MECH 12 *Bt* and RCH 2 *Bt* hybrids and their corresponding non *Bt* hybrids along with one local hybrid, Bunny as check were selected as treatments for the study. The genotypes were sown during first fortnight of July during both the years with a plot size of 80 sq.m (10 m x 8 m) in a randomised block design with 4 replications. The field was kept completely under unsprayed conditions. The incidence of bollworms was recorded from 25 randomly selected plants from each of the test hybrid at weekly interval from square formation to boll maturity. The egg count of *H.armigera* was recorded by observing the terminal portions of the plant while the larval count was taken by observing squares, flowers and bolls of the plant. The incidence of pink bollworm larvae was recorded from 90 days after sowing onwards from all the hybrids by destructive sampling of the green bolls *i.e.*, 50 bolls were picked up randomly from each of the test hybrid which were cut open in the laboratory and larvae/ boll was recorded. Weekly data on different abiotic parameters were recorded from the meteorological observatory and used statistical analysis. The data recorded for both the pests and natural enemies was pooled and used for correlation and multiple linear regression studies. The incidence of spotted bollworm, *Earais vitella* (Fabricius) was almost nil. Hence, the data obtained regarding the incidence of American bollworm and pink bollworm was presented and discussed hereunder.

RESULTS AND DISCUSSION

Incidence of *H.armigera* eggs: The incidence of eggs was observed from 35th standard week (end of August) in all the hybrids except in check. The population of eggs was high during 43rd standard week (end of October) with 0.56, 0.49, 0.66, 0.58 and 0.64 eggs/plant in MECH 12 *Bt*, MECH 12 non *Bt*, RCH 2 *Bt*, RCH 2 non *Bt* and Bunny, respectively (Fig.1). The present findings are in conformity with Soujanya *et al.*, (2008) also reported that the peak population of *H.armigera* was observed from second fortnight of September to the end of October in *Bt* and non *Bt* cotton cultivars.

The mean number of eggs was slightly higher on *Bt* versions compared to their corresponding non *Bt* versions which clearly indicate that the *Bt* genotypes had no adverse effects on egg laying. Among the different test hybrids, the egg laying was less on both MECH 12 *Bt* and MECH 12 non *Bt* hybrids when compared to RCH 2 *Bt*, RCH 2 non *Bt* and Bunny hybrids (Fig.1), which can be attributed to unattractiveness of both MECH 12 *Bt* and MECH 12 non *Bt* hybrids due to severe leafhopper incidence and resemblance of the leaves of MECH hybrids to okra leaves. The present findings recorded that the incidence of *H.armigera* eggs was low in MECH 184 *Bt* when compared to Bunny (NCS 145) hybrid.

The correlation analysis revealed positive association between the incidence of *H.armigera* eggs and all the weather factors except maximum temperature. However, highly significant positive correlation was observed between the incidence of *H.armigera* eggs and evening relative humidity (r = 0.599 to 0.684) in all the hybrids. In addition, the incidence of eggs in RCH 2 *Bt* (r = 0.470) and Bunny (r = 0.477) showed significant positive correlation with morning relative humidity (Table.1).

The multiple linear regression analysis showed that all the weather factors together were responsible for a high and significant variation of 53.0, 54.1, 55.6, 57.4 and 61.2 per cent (R^2 values) in the population of eggs in MECH 12 *Bt*, MECH 12 non *Bt*, RCH 2 *Bt*, RCH 2 non *Bt* and Bunny, respectively. However, none of the weather factors exerted significant individual influence on the incidence of eggs in any of the hybrid (Table.2).

Incidence of *H.armigera* larvae: The larval population was low throughout the crop growth even on non *Bt*'s and check, while it was negligible on *Bt* hybrids. The larval incidence was noticed from 36th standard week (first week of September) to 50th standard week (middle of December) in non *Bt*'s and Bunny, while it was observed for only a short period in *Bt* hybrids with a mean population of 0.04, 0.15, 0.02, 0.22 and 0.24 larvae/plant in MECH 12 *Bt*, MECH 12 non *Bt*, RCH 2 *Bt*, RCH 2 non *Bt* and Bunny,

Table 1. Correlation between weather parameters and incidence of bollworms under unprotected conditions

Pest	Hybrid	Correlation coefficients (r) values				Rain fall (mm)
		Temperature (^{0}C)		Relative humidty (%)		
		Maximum	Minimum	Morning	Evening	
American bollworm egg	MECH 12 *Bt*	-0.151	0.294	0.395	0.605**	0.190
	MECH 12 non *Bt*	-0.175	0.266	0.395	0.599**	0.150
	RCH 2 *Bt*	-0.142	0.335	0.470*	0.669**	0.267
	RCH 2 non *Bt*	-0.191	0.287	0.431	0.638**	0.285
	Bunny	-0.189	0.299	0.477*	0.684**	0.234
American bollworm larva	MECH 12 *Bt*	-0.301	-0.165	0.247	0.200	-0.220
	MECH 12 non *Bt*	-0.383	0.057	0.450*	0.569**	0.032
	RCH 2 *Bt*	-0.316	-0.242	0.219	0.137	-0.244
	RCH 2 non *Bt*	-0.393	0.049	0.462*	0.587**	0.039
	Bunny	-0.414	0.008	0.456*	0.560**	0.013
Pink bollworm larva	MECH 12 *Bt*	-0.571	-0.493	-0.041	-0.274	-0.351
	MECH 12 non *Bt*	-0.534	-0.687*	-0.243	-0.541	-0.526
	RCH 2 *Bt*	-0.507	-0.509	-0.003	-0.336	-0.389
	RCH 2 non *Bt*	-0.535	-0.685*	-0.213	-0.537	-0.517
	Bunny	-0.555	-0.675*	-0.191	-0.515	-0.513

* Significant at 5%; ** Significant at 1%

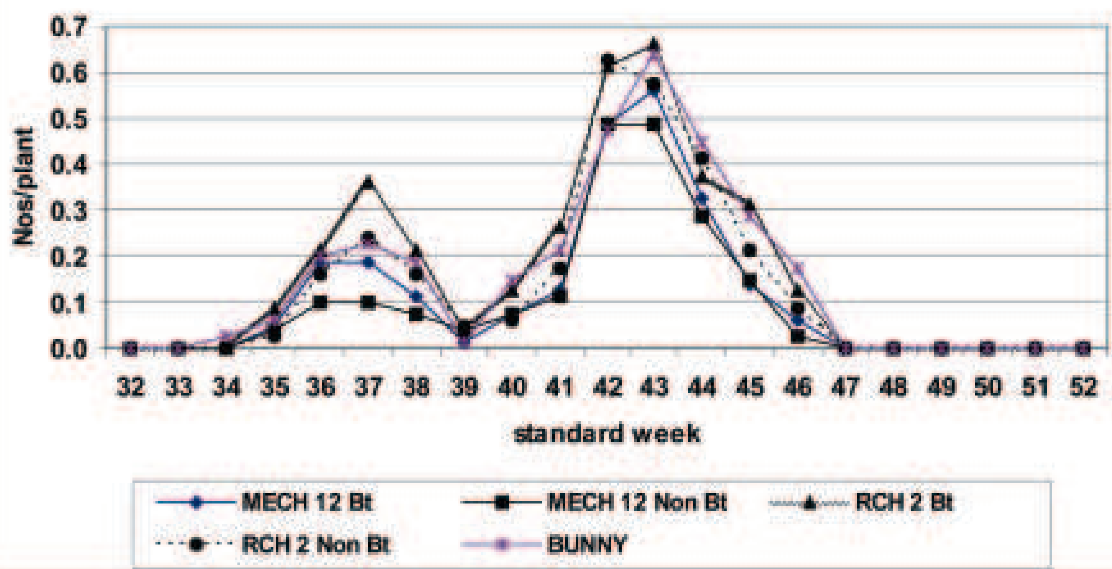
respectively (Fig.2). However Bishnoi *et al.*, (1996) reported the peak activity of *H.armigera* larvae during the month of September. The incidence of *H.armigera* larvae was almost nil in both MECH 12 *Bt* and RCH 2 *Bt* hybrids compared to their corresponding non *Bt* hybrids and check hybrid, Bunny. The present findings recorded that the incidence of *H.armigera* larvae was very low in *Bt* cotton cultivars than their corresponding non *Bt* cultivars.

Though the occurrence of eggs was high, the larval incidence was very low in *Bt* hybrids which clearly indicated the toxic effect of cry protein in *Bt* genotypes against *H.armigera* larvae. However, very low incidence of *H.armigera* larva was observed from 100 -110 days after sowing only in *Bt* hybrids but the incidence of eggs was observed from 60 days after sowing onwards. The present findings clearly indicate that the *Bt* genotypes had no adverse effects on egg laying by *H.armigera*. These observations reported that the *Bt* hybrids can cause upto 82.0 per cent mortality in *H.armigera* larvae.

The correlation analysis showed that the maximum temperature, minimum temperature and rainfall had negative association, where as morning relative humidity and evening relative humidity had positive association with the larval incidence (Table.1). However, significant positive association was observed with morning relative humidity and evening relative humidity in MECH 12 non *Bt* (r = 0.450*; r = 0.569**), RCH 2 non *Bt* (r = 0.462*; r = 0.587**) and check hybrid, Bunny (r = 0.456*; r = 0.560**). The present findings are contradicting with Mohapatra *et al.* (2004) who reported that morning relative humidity had significant negative influence on larval population of American bollworm.

The multiple linear regression analysis showed that the total variation in larval population contributed by all the weather factors was very low and non significant in *Bt* hybrids, *i.e.* 21.4 per cent in MECH 12 *Bt* and 19.8 per cent in RCH 2 *Bt*, while it was high and significant in MECH 12 non *Bt*, RCH 2 non *Bt* and Bunny hybrids which was 55.7, 58.0 and 56.7 per cent (R^2 values), respectively. However, none of the weather variables exerted significant individual impact on the larval incidence irrespective of the test hybrid (Table.2). The present findings are in accordance with Srinivasa Rao (2004) who reported that the total influence of weather factors on the larval incidence was high in Bunny compared to *Bt* hybrids.

Fig.1: Seasonal Incidence of *H.armigera* eggs under unprotected conditions



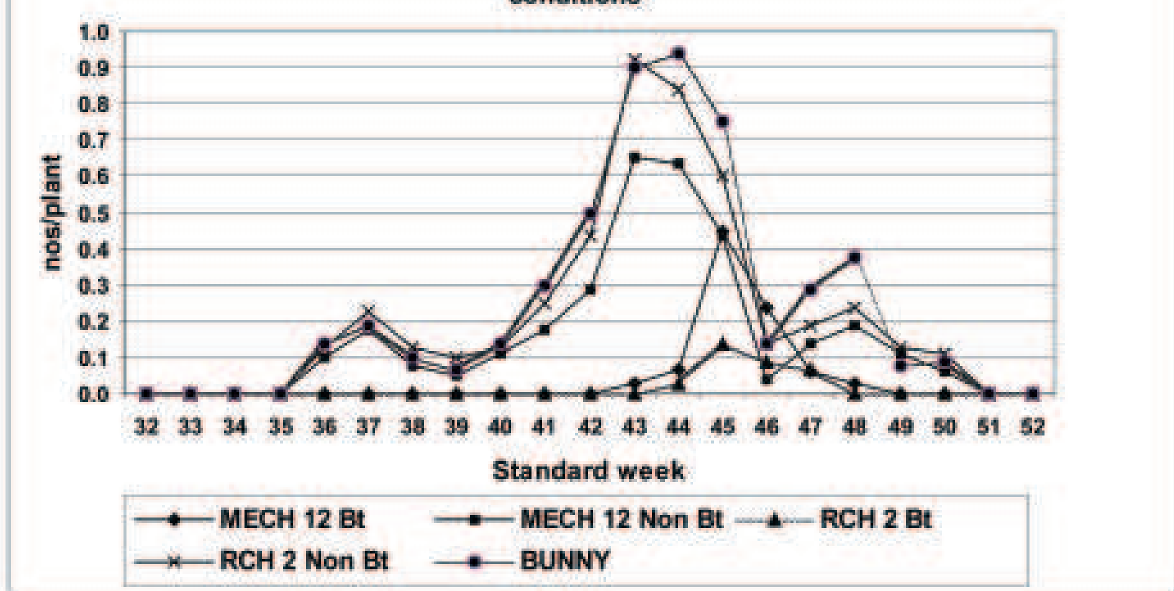


Fig.2: Seasonal Incidence of *H.armigera* larvae under unprotected conditions

Incidence of pink bollworm larvae : The larval incidence of pink bollworm was observed from first week of November in non *Bt*'s and Bunny, where as it was delayed by 3-4 weeks in MECH 12 *Bt* and RCH 2 *Bt* hybrids. The peak population of larvae was observed during first week of January in MECH 12 non *Bt* and RCH 2 non *Bt* hybrids with 2.10 and 2.20 larvae/boll, respectively while it was during the end of December in Bunny hybrid with 2.34 larvae/boll. The larval incidence was further delayed in *Bt* hybrids which was observed during second week of January with only 0.29 and 0.25 larva/boll in MECH 12 *Bt* and RCH 2 *Bt* hybrids, respectively (Fig.3). However, Gupta *et al.* (1990) and Tomar *et al.* (2004) reported the peak incidence of pink bollworm from second week of October to second week of December. The incidence of pink bollworm larvae was almost nil in both MECH 12 *Bt* and RCH 2 *Bt* hybrids while it was very high in non *Bt*'s and Bunny hybrid.

The correlation analysis revealed that all the weather parameters had negative association with the larval incidence of pink bollworm in all the hybrids which is concurrent with Khan *et al.*, (2002) who reported that the pink bollworm infestation was negatively correlated with abiotic factors like temperature (^{0}C) and rainfall (mm). However, minimum temperature showed significant negative influence on the larval incidence of pink bollworm in MECH 12 non *Bt* (r= -0.687), RCH 2 non *Bt* (r = -0.685) and Bunny (r = -0.675) hybrids only (Table.1). The present findings are in accordance with Gupta *et al.* (1990) who reported significant negative influence between temperatures and larval incidence of pink bollworm. Mohapatra *et al.* (2004) also reported negative association between weather factors and pink bollworm larvae except with rainfall. But the present findings differ with the observations of Gopalaswamy *et al.* (2002) who reported that there is a significant positive association between green boll damage and temperature (maximum temperature and minimum temperature).

The multiple linear regression analysis revealed that the collective influence of all the weather factors on larval incidence of pink bollworm was very high *i.e.* 69.1, 86.5, 69.4, 87.9 and 89.0 per cent (R^2 values) in MECH 12 *Bt*, MECH 12 non *Bt*, RCH 2 *Bt*, RCH 2 non *Bt* and Bunny, respectively which was significant in non *Bt*'s and Bunny only (Table 2). The results are in accordance with Rahaman and Goud (2007) who reported upto 76.12 and 84.33 per cent influence by all the weather parameters on the incidence of pink bollworm larvae in green bolls in *Bt* and non *Bt* cotton, respectively. Further, maximum

Table 2. Multiple linear regression analysis between weather parameters and the incidence of bollworms under unprotected conditions

Pest	Hybrid	Regression equation	R^2
American bollworm egg	MECH 12 *Bt*	= 2.14 – 0.037 X1 + 0.012 X2 – 0.028 X3 + 0.020 X4 – 0.0009 X5	0.530*
	MECH 12 non *Bt*	= 2.01 – 0.036 X1 + 0.012 X2 – 0.025 X3 + 0.018 X4 – 0.001 X5	0.541*
	RCH 2 *Bt*	= 1.65 – 0.031 X1 + 0.012 X2 – 0.027 X3 + 0.023 X4 – 0.001 X5	0.556*
	RCH 2 non *Bt*	= 3.01 – 0.062 X1 + 0.022 X2 – 0.032 X3 + 0.021 X4 – 0.0009 X5	0.574*
	Bunny	= 1.93 – 0.028 X1 + 0.006 X2 – 0.031 X3 + 0.026 X4 – 0.001 X5	0.612**
American bollworm larva	MECH 12 *Bt*	= 0.04 – 0.017 X1 + 0.007 X2 + 0.004 X3 + 0.0007 X4 – 0.001 X5	0.214
	MECH 12 non *Bt*	= 3.75 – 0.101 X1 + 0.037 X2 – 0.025 X3 + 0.015 X4 – 0.002 X5	0.557*
	RCH 2 *Bt*	= -0.10 – 0.001 X1 + 0.0001 X2 + 0.002 X3+ 0.0001 X4- 0.0004 X5	0.198
	RCH 2 non *Bt*	= 4.82 – 0.112 X1 + 0.032 X2 – 0.041 X3 + 0.027 X4 – 0.002 X5	0.580*
	Bunny	= 5.09 – 0.130 X1 + 0.041 X2 – 0.038 X3 + 0.026 X4 – 0.003 X5	0.567*
Pink bollworm larva	MECH 12 *Bt*	= 4.87 - 0.216 X1 + 0.038 X2 + 0.025 X3 - 0.017 X4 - 0.053 X5	0.691
	MECH 12 non *Bt*	= 38.57 - 1.426 X1* + 0.277 X2 + 0.107 X3 - 0.131 X4 - 0.272 X5	0.865*
	RCH 2 *Bt*	= 3.85 - 0.178 X1 + 0.042 X2 + 0.023 X3 - 0.017 X4 - 0.049 X5	0.694
	RCH 2 non *Bt*	= 39.58 - 1.501 X1* + 0.292 X2 + 0.128 X3 - 0.143 X4 - 0.286 X5	0.879*
	Bunny	= 43.35 - 1.671 X1* + 0.336 X2 + 0.145 X3 - 0.155 X4 - 0.342 X5	0.890*

* Significant at 5%; ** Significant at 1%

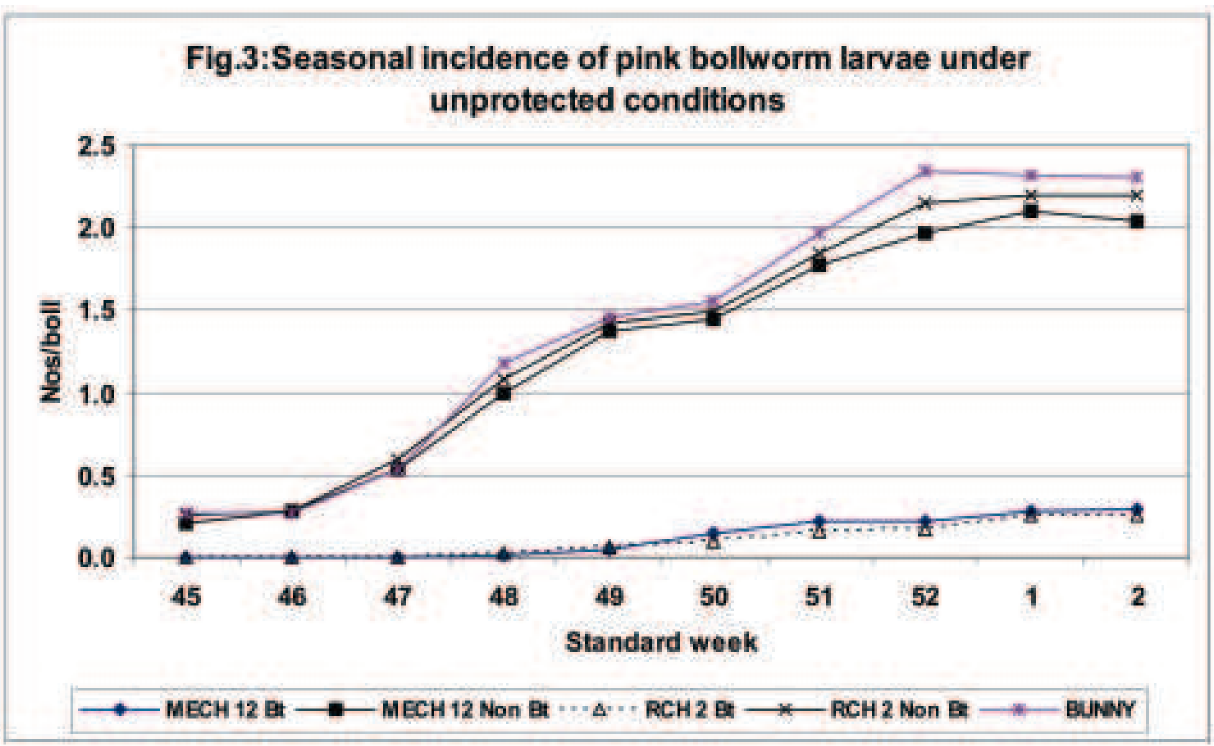


Fig.3: Seasonal incidence of pink bollworm larvae under unprotected conditions

temperature was found to exert independent and significant negative impact on pink bollworm larval incidence in non *Bt*'s and Bunny. Thus, for every 1^{0}C increase in maximum temperature, the corresponding decrease in the larval population was 1.426, 1.501 and 1.671 larvae/boll in MECH 12 non *Bt*, RCH 2 non *Bt* and Bunny hybrids, respectively (Table.2). However, Srinivasa Rao (2004) reported upto 80 per cent of total variability in larval incidence of pink bollworm due to all the weather variables in different *Bt* hybrids.

CONCLUSION

The present study indicated that the *Bt* genotypes had significant adverse effects on the incidence of major bollworms of cotton viz., *H.armigera* and *P.gossyipiella* since the larval incidence was very low in *Bt* versions compared to their corresponding non *Bt* versions and check hybrid, Bunny besides the larval incidence was also delayed by 2-3 weeks in *Bt* versions. The influence of weather parameters was also very low on the larval incidence in *Bt* versions which might be due to very low incidence of larvae when compared to non *Bt* versions. The results of present study clearly indicated that the *Bt* cotton genotypes incorporated with *cry* 1Ac gene offers good protection against both *H.armigera* and *P.gossyipiella* with their inbuilt resistance.

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Relationship of weather parameters with population of major sucking pests in transgenic cotton

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ABSTRACT : Studies were conducted on population dynamics of sucking pests on transgenic *Bt* cotton (NCS 145) and influence of weather parameters on their incidence at Research Farm, Cotton Research Station, Nanded during rainy *kharif*, 2007-2008 to 2009-2010 under unprotected conditions. The appearance of major sucking pests namely, aphids, leafhoppers, thrips and whiteflies were observed during early growth stage and continued till the end of crop growth. There were three and two population peaks of aphids during 2007-2008 and 2008-2009, respectively while during 2009-2010 the peak incidence of aphids was observed in 32nd Standard Meteorological Week (SMW). The peak incidence of leafhopper was observed from 37th to 42nd SMW. It was 34th to 38th SMW for thrips and 38th to 43rd SMW for whiteflies. The aphid incidence showed significant negative relationship with minimum temperature and rainfall and positive relationship with relative humidity while none of the weather parameters have significant relationship with leafhoppers. Minimum temperature and rainfall had significant positive correlation with the incidence of thrips. The correlation of white fly population was positive with maximum and minimum temperatures. The highest R^2 value (55.6 %) was observed for thrips.

Key words : Correlation, standard meteorological week, sucking pests, transgenic cotton, weather parameters

Cotton is an important fibre and cash crop of global significance and is cultivated in tropical and subtropical regions of more than 111 countries. India has the largest acreage (101.52 lakh ha) under cotton, producing 295 lakh bales cotton in 2009-2010. The release of transgenic Cotton for commercial cultivation in India has been a historical event in reducing the losses due to bollworms and in turn increasing the productivity. Though within a span of eight years 90 per cent of area in India came under *Bt* umbrella, the incidence of sucking pests inflicting losses increased to the great extent. In India, out of 162 species of insect pests, 12 are considered as key pests which cause upto 50-60 per cent losses from sowing to maturity (Dhawan, 1999). After introduction of bollgard technology, a complex of sucking pests *viz.*, aphids (*Aphis gossypii* Glov.), leafhoppers (*Amrasca biguttula biguttula* Ishida), thrips (*Scirtothrips dorsalis* Hood) and whitefly (*Bemisia tabaci* Genn.) occupy a major pest status and cause considerable damage in *Bt* cotton. Information on seasonal activity of sucking pests on transgenic cotton helps to plan management strategy. Keeping this in view, the present studies were focused on location specific seasonal occurrence of sucking pests and its relation with weather parameters.

MATERIALS AND METHODS

The field experiments were conducted from 2007-2008 to 2009-2010 on population dynamics of cotton sucking pests at Cotton Research Station, Nanded under rainfed conditions. Transgenic cotton Bunny *Bt* (NCS 145) BG I was sown in a non replicated plot of 100 m^2 at 90 x 60 cm spacing. All the agronomical practices were followed to raise the good crop except crop protection measures. The population of sucking pest complex was recorded at weekly intervals with the appearance of pest and continued till the end of crop growth. The observations were recorded on nymphs and adults of aphids as well as jassids and adults of thrips as well as whiteflies from three leaves each from top, middle and bottom canopies of the randomly selected 10 plants.

Weather parameters like maximum and minimum temperature, morning and evening relative humidity and rainfall were recorded in meteorological observatory of experimental farm for studies. The average data of three successive years of sucking pests and weather factors were subjected to correlation and regression analysis to work out the relationship between pest incidence and weather parameters.

RESULTS AND DISCUSSION

Incidence of sucking pests : The mean incidence of aphids / 3 leaves was observed from 32nd (6-12 Aug), 33rd (13-19 Aug) and 30th (23-29 July) SMW during 2007-2008 to 2009-2010, respectively. The population of aphids was observed throughout crop growth. During 2007-2008, three population peaks of aphids 22.40, 21.70 and 26.50 /3 leaves were observed during 32nd (6-12 Aug), 46th (12-18 Nov) and 47th (19-25 Nov) SMWs weeks respectively. However in 2008-2009 two peaks of mean aphid population of 27.6 and 25.20 /3 leaves were recorded during 34 SMW (20-26 Aug) and 35 SMW (27 Aug-2 Sept), respectively. During 2009-2010 the highest population of aphids 19.50/3 leaves was observed during 32nd SMW (6-12 Aug.). Prasad *et al.,* (2008) reported that the incidence of aphids was observed from 35th to 37th SMWs during 2001-2002 to 2002-2003 seasons and from 32nd to 34th SMWs during 2003-2004 to 2005-2006.

Incidence of leaf hopper was commenced at early vegetative growth phase *i.e.* 32nd (6-12 Aug), 33rd (13-19 Aug) and 30th (23-29 July) SMWs during 2007-2008 to 2009-2010, respectively and continued till late reproductive crop growth stage 45th SMW. During 2007-2008 and 2008-2009 the peak population of mean leafhoppers was 6.90 and 5.70/3 leaves in 40 SMW (1-7 Oct) and 42 SMW (15-21 Oct) respectively. However, during 2009-2010 there were two peaks of leafhopper population with 15.20 and 14.90 leafhoppers /3 leaves in 37 SMW (10-16 Sept) and 40 SMW (1-7 Oct), respectively. Jeyakumar *et al.,* (2008) observed maximum activity of jassid during 30th SMW in *Bt* cotton. Tomar *et al.,* (2004) reported the peak incidence of leafhoppers during mid July to end of October (Table 1).

The incidence of thrips was noticed from 32nd (6-12 Aug), 33rd (13-19 Aug) and 30th (23-29 July) SMWs during 2007-2008 to 2009-2010, respectively. There were two population peaks of thrips 67.10 and 89.60 /3 leaves during 34th (20-26 Aug) and 35th SMW (27-2 September) during 2007-08 season. However, during 2008-2009 and 2009-2010, maximum population of thrips 19.60 and 20.50/3 leaves were recorded during 36th (3-9 September) and 38th (17-23 September) SMW, respectively. Results of three seasons clearly indicated that the active window of thrips population was during August and September. Prasad *et al.,* (2008) observed peak population of thrips (42.4/3 leaves) on cotton during 37th SMW of 2002-2003 and reported peak activity of thrips during August and September of 2000-2001 to 2004-2005 seasons.

The population of whitefly was noticed from early crop growth period and continued till reproductive growth phase of the cotton crop. Peak incidence of whitefly, 6.70 and 7.90/3 leaves was observed during 40th (1-7 October) and 39th (24-30

Table 1. Peak incidence of sucking pests in Bt cotton (2007-2010)

Year	Std. Metro. Week	Peak incidence	Temperature ^{0}C		Realtive humidity (%)		Rainfall (mm)
			Maximum	Minimum	Morning	Evening	
Mean number of aphids / 3 leaves							
2007-2008	47	26.50	21.70	7.70	73.14	60.71	0.00
2008-2009	34	27.60	32.17	19.57	85.57	76.43	40.80
2009-2010	32	19.50	37.71	19.00	76.43	70.71	2.40
Mean number of leafhoppers / 3 leaves							
2007-2008	40	6.90	26.20	19.80	88.85	61.42	0.00
2008-2009	42	5.70	32.80	19.86	56.86	58.86	0.00
2009-2010	37	15.20	32.29	18.00	36.87	22.66	20.20
Mean number of thrips / 3 leaves							
2007-2008	35	89.60	26.40	20.40	90.14	61.71	154.00
2008-2009	36	19.60	31.43	19.23	82.43	70.14	83.80
2009-2010	38	20.50	34.71	19.00	16.81	20.92	0.00
Mean number of whiteflies / 3 leaves							
2007-2008	40	6.70	37.20	19.80	88.85	61.42	0.00
2008-2009	39	7.90	30.97	20.03	83.57	76.86	0.00
2009-2010	43	10.90	33.57	14.14	11.11	16.01	0.00

Sept.) SMWs of 2007-2008 and 2008-2009, respectively. However, during 2009-2010, two population peaks of whitefly, 10.60 and 10.90/3 leaves were recorded in 38th (17-23 Sept.) and 43rd (22-28 Oct) SMW respectively. The population of whiteflies was very low during the initial periods of crop growth. However, maximum population of whiteflies was observed during September – October. Jeyakumar *et al.*, (2008) recorded higher population of whitefly in 31st , 33rd , 36th and 37th SMW on *Bt* cotton. Tomar *et al.,* (2004) and Prasad *et al.,* (2008) were also reported the peak incidence of whiteflies during October-November.

Influence of weather parameters : The correlation between abiotic factors and population of sucking pests is presented in Table 2.

Aphids : There was positive and negative correlation between the population of aphids with all the weather parameters . However, significant negative correlation was observed with the minimum temperature and rainfall. The relative humidity showed positive correlation with the population of aphids which was non significant. The present findings are in agreement with Shivanna *et al.,* (2009).

Table 2. Correlation between population of sucking pests and weather parameters (2007-2010)

Weather parameters	Aphids	Leaf hoppers	Thrips	Whiteflies
Tmax	-0.210	0.322**	-0.172	0.305**
Tmax1	-0.183	0.279*	-0.193	0.300**
Tmin	-0.346**	0.255	0.384**	0.032
Tmin1	-0.203	0.202	0.297**	0.046
RHI	0.121	-0.406**	0.182	-0.531**
RHI1	0.105	-0.268*	0.167	-0.487**
RHII	0.170	-0.507**	-0.040	-0.581**
RHII1	0.201	-0.311**	-0.036	- 0.553
RF	-0.208	-0.018	0.588**	**-0.154
RF1	-0.272*	0.202	0.225	-0.064

* ** Significant at P=0.01 and P=0.05 level, respectively

Leafhoppers : There was significant positive correlation of jassid population with maximum temperature. Population of leaf hoppers showed significant negative correlation with morning and evening RH, while the relationship was non significant with the other parameters. The present findings are in agreement with the findings of Singh *et al.,* (2004) who reported that significant positive influence of temperature on the population of jassids. Bishnoi *et al.,* (1996) significant relationship between build up of jassids and mean air temperature and relative humidty.

Thrips : Thrips population was significantly and positively correlated with minimum temperature and rainfall. Morning RH have non-significantly positive influence on population of thrips whereas other paramenters are non significant and negatively correlated with population of thrips. Dandale *et al.,* (2007) and Shivanna *et al.,* (2009) reported significant positive correlation with minimum temperature and population of whitefly. These findings are in conformity with the present findings.

Whitefly : The correlation of whitefly population was positive and significant with maximum temperature whereas the whitefly population was positively correlated with minimum temperature. However, RH had negatively significant influence on the whitefly population and rainfall had also negatively non significant impact. Rote and Puri (1991), Gupta *et al.*, (1998), Sharma *et al.*, (2004) and Kaur *et*

Table 3. Multiple linear regression analysis between population of sucking pests and weather parameters. (2007-2010)

Pests	Regression equations
Aphids	Y= 32.19 - 0.893Tmax + 0.213Tmax1 - 0.438Tmin + 0.131Tmin1 – 0.026RHI-0.136RHI1 – 0.045RHII + 0.290RHII1 + 0.006RF – 0.060RF2 R^2 = 0.257 SE = 7.70 Multiple R = 0.507
Leafhoppers	Y= 0.534 + 0.277Tmax - 0.218Tmax1+ 0.174Tmin + 0.122Tmin1 - 0.044RHI - 0.040RHI1 – 0.140RHII + 0.052RHII1 + 0.002RF + 0.015RF2 R^2 = 0.470 SE = 2.84 Multiple R = 0.686
Thrips	Y= 28.15 + 0.972Tmax – 2.430Tmax1 + 1.508Tmin + 0.448Tmin1-0.068RHI +0.100RHI1 – 0.515RHII + 0.251RHII1 + 0.319RF – 0.149RF2 R^2 = 0.556 SE = 12.15 Multiple R = 0.746
Whitefly	Y= 2.889 + 0.115Tmax – 0.105Tmax1 + 0.031Tmin + 0.246Tmin1- 0.020RHI + 0.019RHI1 – 0.016RHII - 0.049RHII1 - 0.016RF + 0.005RF2 R^2 = 0.418 SE = 2.46 Multiple R = 0.646

al., (2009) reported positive association between temperatures and negative with RH between whitefly population which are in agreement with the present findings.

The multiple linear regression analysis : The multiple linear regression analysis indicated that the total influence of all the weather parameters was high and positive up to 55.60 per cent (R^2=0.5560) on the population of thrips. The influence of all the weather parameters was low and non significant on aphids (R^2=0.2570), leafhoppers (R^2=0.470) whiteflies (R^2=0.418) (Table 3).

The present findings are in line with the findings of Prasad *et al* (2008) who reported that the influence of all the weather parameters was low and non significant on aphids (R^2 = 0.3662), high and significant on leafhoppers (R^2 = 0.5178) and whitefly population (R^2 = 0.6026).

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Impact of integrated pest management technology on insect pest incidence, their natural enemies and economic viability of *Bt* seed cotton

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ABSTRACT: A field study was conducted at Balwada village of Khandwa district under Technology Mission of Cotton – Mini Mission –I during 2005-2006 and 2006-2007 to evaluate the performance of *Bt* cotton hybrid under IPM, farmer practice (FP) and unprotected condition (Check). The minimum population of aphids and leafhoppers were recorded under farmers practices (13.4 and 3.93/ 3 leaves) and it was significantly differ from IPM which was showed that its population of these insect reduced by the frequent application of insecticides effectively than IPM block and check. The similar trends have also been observed in thrips. The population of whiteflies were significantly minimum (12.8/3 leaves) in IPM block and it was *at par* with farmers block (13.9/3 leaves) and check. The significantly minimum *Helicoverpa armigrea* (Hubner) and *Pectinophora gossypiella* (Saunders) larval populations were found under farmers practice and *at par* with IPM. The significantly low per cent incidence of square and boll damage was noticed in IPM block *i.e.* 0.47 and 0.23 followed by farmers practices 0.65 and 0.47. The populations of lady bird beetle and green lace wing were significantly maximum under IPM (1.3/plant) and it was differ from unprotected plot (0.85/plant) and farmers practice (0.11/plant). The significantly highest seed cotton yield (25q/ha) was found in IPM block followed by farmers practice (19.50q/ha) and unprotected plot (12.25q/ha). However the cost benefit ratio was high from IPM block (1:2.29) as compared to farmers practice (1:1.52) and unprotected plot (1:1.40).

Key words: *Bt* cotton hybrid, CB ratio, FP, IPM, net profit, plant protection cost

The biotic and abiotic factors are major hurdles for achieving target yield. Out of biotic factors sucking pest *viz.,* leafhoppers, *Amrasca biguttula biguttula* (Ishida), whitefly, *Bemisia tabaci* (Gennadius), Thrips, *Thirps tabaci* Linndeman and bollworms complex, *viz.* American bollworm, *Helicoverpa armigera* (Hubner), spotted bollworm, *Earias* spp. and pink bollworm, *Pectinophora gossypiella* (Saunders) are the key insect pest of cotton and serious threat to cotton production in India causing 50-60 per cent average loss in yield of seed cotton IPM technology helps in conservation of natural biodiversity as well as eco friendly insect; apart from reduce the cost of plant protection and increase the productivity and profitability (Garg, *et al.,* 2007).

The genetically modified transgenic *Bt* cotton was commercially available in India from 2002 and found suitable for farmers due to its favourable role to suppressing the infestation of bollworm complex and also a integral part of IPM (Bombawale *et al.,* 2004). However, contradictory reports are available on the incidence of insect pest on transgenic cotton hybrids (Cuie and Xia 2000). The development of transgenic cotton has resulted in an immense increase in the seed cotton yield and reduction in the insecticidal sprays (Barwale *et al.,* 2004). It is necessary to test the impact of IPM strategies on *Bt* cotton and to formulate a suitable IMP module.

MATERIALS AND METHODS

The experiment was conducted at Balwada village of Khandwa under Technology Mission on Cotton during 2005-2006 and 2006-2007 under rained conditions in shallow black soils. RCH 2 *Bt* was sown during mid of June at a spacing 120 x 90 cm. The agronomic practices were taken up as per the recommendations except for plant protection measures. Three different modules were tested as ; IPM block, farmers block. and unprotected block (check), having on area 0.40 ha in all modules.

IPM module : Seed treatment with Imidacloprid @ 7g/ kg seed, spraying of Imidacloprid 17.8 SL@100 ml/ha at 50 DAS, intercropping with green gram, merigold as trap crops, cowpea as border crop, random planting of sorghum or maize; erection of bird perches, installation of pheromone traps; spraying with 5 per cent NSKE and need based application of insecticides. Farmers block (FB) had insecticidal intervention taken up for every 15 days in *Bt* hybrids. Unprotected block (Check) had *Bt* cotton kept under completely unprotected conditions.

The incidence of sucking pests, bollworms, fruiting bodies (square, green boll, locule) damage and the occurrence of natural enemies were recorded at weekly intervals from 50 randomly selected and tagged plants. Sucking pest, such as aphid, leafhoppers, whiteflies and thrips were recorded from three leaves each one from top, middle and bottom canopies. The bollworms eggs, larvae and fruiting bodies and natural enemies were observed from whole plant. Cost of cultivation and yield were recorded and cost benefit ratio was calculated. The incidence of different insect pest and damage were given as seasonal mean and cost of cultivation as mean for both the year.

RESULTS AND DISCUSSION

The seasonal mean data indicated that the minimum population of aphids was recorded under farmers practices (13.4/3 leaves) and it was significantly differ from IPM (18.2/3 leaves) and unprotected block (check) (25.6/3 leaves. The population of leafhoppers was significantly minimum in farmers block (3.93 leaves) while it was *at par* with population observed in IPM block (4.2/3 leaves). The significantly maximum population of leafhoppers were found in unprotected block (7.2/3 leaves) which showed that its population was reduced by the frequent application of insecticides effectively than IPM block and check (Table1). The similar trends have also been observed in thrips population whereas population of thrips were recorded maximum in unprotected blocks (23.04/3 leaves) and found *at par* with IPM block (18.3/3 leaves).However the population of whiteflies were significantly minimum (12.8/3 leaves) in IPM block and it was *at par* with farmers block (13.9/3 leaves) and unprotected check (14.8/3 leaves) (Table1) indicating resurgence of this insect due to recurrent spraying of insecticides. In general the population of the entire sucking pest was maximum in unprotected conditions as compared to IPM and farmers practices modules. The minimum population of sucking pest under farmer's practices can be attributed to insecticidal interventions at frequent intervals, resulted in resurgence of whiteflies. The efficacy of Imidacloprid@7 g/kg of seed as seed dresser observed similar to earlier finding in controlling to aphid, leafhoppers, thrips and whiteflies up 60 days (Choudhary *et al.,* 2006a). The spraying of Imidacloprid 17.8 SL@100 ml/ha at ETL was reported highly effective to control the aphid, leafhoppers, thrips and whiteflies. It has been reported that the cotton crop bordered by cowpea promoted the population buildup of lady bird beetle and supported significantly lower population of sucking pest (Garg, *et al.,* 2007). Sohi *et al.,* (2004) reported that the incidence of leafhoppers and whiteflies/leaf were found low in IPM block as compared to farmers practice and check.

The minimum number of egg of *H. armigera* was recorded in farmers practice (0.30/plant) and it was did not differ significantly from IPM (0.50/ plant) and unprotected block plot (0.70/plant).The average larval population was very low and never crossed the ETL in any of the module due to the toxic effect of *Bt* protein and whereas significantly minimum larval populations were found under farmers practice (0.02/plant) and *at par* with IPM(0.04/plant) however, it was significantly differ from cheek (0.09/plant

Table 1. Seasonal activity of sucking pest and egg and larvae population of *H. armigera* in *Bt* hybrids

Treatments	Population of sucking pest/plant				Population of eggs and larvae of *H. armigera*/plant	
	Aphid	Leafhoppers	Thrips	Whitefly	Eggs/plant	Larvae/ plant
IPM	18.2(4.32)a	4.2(2.11)a	18.3(4.24)a	2.8(1.73)a	0.5 (0.99)a	0.04(0.73)a
Farmers practice	13.4(3.72)b	3.9(2.04)ab	15.3(3.92)ab	4.8(2.25)ab	0.3(0.88)ab	0.02(0.72)ab
Unprotected (Check)	25.6(5.10)c	7.2(2.72)c	23.4(4.85)bc	3.9(2.05)bc	0.7(1.01)abc	0.09(0.76)bc

Figures in parentheses are “X+0.5 transformed values
Figures followed by same alphabets did not differ significantly with each other by least significance (p=0.05)

Table 2. Seasonal incidences of bollworms and pink bollworm larvae population

Treatments	Seasonal incidence			
	Square damage	Boll damage	Locule damage	Pink bollworm larave
IPM	0.47(0.96)a	0.23(0.84)a	2.1(1.49)a	0.28(0.88)a
Farmers Practice	0.65(1.03)ab	0.47(0.97)ab	2.9(1.74)b	0.43(0.96)ab
Unprotected	1.8(1.43)c	1.75(1.47)bc	4.8(2.23)c	0.67(1.06)c

Figures in parentheses are "X+0.5 transformed values
Figures followed by same alphabets did not differ significantly with each other by least significance (p=0.05)

(Table 1). Spraying of NSKE 5 per cent reduced the population of eggs under IPM. However it can be attributed to insecticidal sprays under farmers practice. Sohi *et al.,* (2004) reported that the larval incidence of *H. armigera*, *Earias* spp and *P. gossypiella* in intact green fruiting bodies were low in IMP fields.

The present studies showed that the average minimum per cent square and boll damage were noticed in IPM block *i.e.* 0.47 and 0.23 and followed by farmers practices 0.65 and 0.47. The significantly maximum per cent square and boll damage were found under check (1.8 and 1.75). Kulkarni *et al.,* (2004) reported that the mean boll damage was 12.16 per cent in *Bt* cotton with IPM against 14.58 per cent in *Bt* cotton with insecticides. Bombawale *et al.,* (2004) reported that significant reduction in boll damage by the bollworm in *Bt* cotton with IPM which was 11.5 per cent as against 29.4 per cent in farmers practices (Table 2).

The incidence of pink bollworm through sampling method showed that the significantly lowest mean number of larvae were observed in IPM (2.1/boll) and found differ from farmers practice (2.9/boll) and unprotected control (4.8/ boll). The significantly minimum pink bollworm larvae were observed under IPM (0.28/ 10 bolls) and it was *at par* with farmers practice (2.9/ 10 bolls) however significantly maximum population of pink bollworm larvae were noticed in unprotected control (0.67/ 10 bolls).

The populations of lady bird beetle and green lace wing were significantly maximum under IPM (1.3/plant) and it was differ from unprotected plot (0.85/plant) and farmers practice (0.11/plant) (Table 3). The population of beneficial insect were conserved under IPM plot because of intercrop, border crop, spraying of botanical insecticide like NSKE and seed treatment in corroborate with result of Choudhary, *et al.,* (2006b) and Kulkarni *et al.,* (2004) spraying. The population of lady bird beetles and green lace wings were increased satisfactory in *Bt* cotton IPM plots over control (Garg, *et al.,* 2007). Dhawan *et al.,* (2011) reported that the population of natural enemies during early season remained high in IPM blocks.

The significantly highest seed cotton yield (25q/ha) was found in IPM block followed by farmers practice (19.50q/ha) and unprotected plot (12.25q/ha). However the cost benefit ratio was gain high from IPM block (1:2.29) as compared to farmers practice (1:1.52) and unprotected plot (1:1.40) (Table 4).Nevertheless seed cotton yield, net profit and cost benefit ration were higher than farmers practice due to inclusion of all technique of IPM at proper time interval. The low plant protection cost, maximum net profit, more seed cotton yield and higher cost benefit ratio have also recorded by Garg, *et al.,* 2007 and line with the present findings.

The number of interventions were only five in IPM with low cost technique like spraying of NSKE led to low plant protection cost of Rs. 2150/ha under IPM as against nine insecticides interventions with Rs. 6680/ha under farmers practice module which indicated low seed cotton yield, net profit and cost benefit ratio. The present study showed fact that the use of all techniques of IPM lead to reduce the cost of cultivation, increase the net profit and population of eco friendly insects. The present

Table 3. Seasonal mean population of eco friendly insect under various modules.

Treatments	Population /plant
IPM	1.3 (1.28)a
Farmers practice	0.11(0.77)b
Unprotected (Check)	0.85(1.14)c

Figures in parentheses are "X+0.5 transformed values
Figures followed by same alphabets did not differ significantly with each other by least significance (p=0.05)

Table 4. Economics of different modules of *Bt* cotton

S.N.	Particulars	IPM	FP	Unprotected block
1.	Plant protection cost (Rs./ha)	2150	6680	0
	Interventions			
	• Botanicals (NSKE)	01	0	0
	• Application of Insecticides	04	08	0
	Total interventions	05	08	0
2.	Yield (q/ha)	25a	19.50b	12.25c
3.	Gross income (Rs./ha)	46250	36075	22662
4.	Cost of cultivation (Rs./ha)	20145.50	23779	16150
5.	Net profit (Rs./ha)	26104.50	12296	6512.5
6.	Cost benefit ratio	1:2.29	1:1.52	1:1.40

Cost of seed cotton @ Rs. 1850/q.
Figures followed by same alphabets did not differ significantly with each other by least significance (p=0.05)

results are in line with Garg, *et al.,* 2007 that reported 60 per cent reduction in insecticidal spray in IPM block and also reported that higher cost benefit ratio in comparison with non IPM block. Dhawan *et al.,* 2011 found that 38.39 per cent reduction in number of sprays in IPM village in comparison to non IPM villages.

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Integrated disease management of Alternaria leaf spot on *Bt* cotton through fungicides

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ABSTRACT: The fungicides were evaluated under field conditions during 2010-2011 and 2011-2012. Three sprays were given at 65, 85 and 105 DAS. Two years pooled results revealed that seed treatment (ST) with Vitavax power (0.3%) + foliar spray (FS) of Propiconazole (0.1%) significantly lowered Alternaria leaf spot per cent disease index (5.54 PDI) which was *on p*ar with ST with Vitavax power (0.3%) + FS of Tebuconazole (0.1%) (6.92 PDI) followed by ST with Vitavax power (0.3%) + FS of Hexaconazole (0.1%) (8.47 PDI). Similarly, the maximum yield of 2777.39 kg/ha was recorded in ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) which was *on par* with ST with Vitavax power (0.3%) + FS of Tebuconazole (0.1%) (2685.80 kg/ha) and ST with Vitavax power (0.3%) + FS of Hexaconazole (0.1%) (2554.02 kg/ha), respectively. However, the ST with Vitavax power (0.3%) + FS of Hexaconazole (0.1%) recorded highest incremental benefit: cost of 5.24 follwed by ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) of 4.46 remained as next best fungicide.

Key words: *Bt* cotton, disease, fungicides, integrated, management

Cotton, "The White Gold" enjoys a pre-eminent status among all cash crops in the country. The economic importance is mainly from its fiber. The lint is universally used as textile raw material. Cotton seed is the second most important source of vegetable oil and the cotton seed cake is the rich source of high quality protein for animal feed or with careful processing, for human food. It is also used in manufacturing industrial products such as soap and paints. The hull forms about 40 per cent of the seed and is used mainly as fertilizers or roughage in stock feed. The low productivity of cotton in Karnataka attributed to many factors, one of which is the losses due to diseases although insect pests continue to be a major production constraint. A large number of fungal, bacterial, viral and nematode diseases have been reported on cotton crop right from early stage to maturity. Among them, the economically most important one are bacterial blight, Alternaria leaf spot, grey mildew, rust and vascular wilts which occur throughout the world.

Keeping this in view, the present investigations were under taken to study the integrated disease management of Alternaria leaf spot on *Bt* cotton through fungicides

MATERIALS AND METHODS

Field experiments were conducted during *kharif,* 2010-2011 and 2011-2012 at Agricultural Research Station, Dharwad Farm under rainfed conditions to know the efficacy of effective fungicides selected under *in vitro* study and those fungicides were used against Alternaria leaf spot in *Bt* cotton under natural field conditions. The experiment was laid out in randomized block design (RBD) with three replications with 6.0 x 5.4 m plot size. Susceptible genotype Bunny *Bt* was used. The treatments details are as below : T_1: ST with Vitavax power (0.3%) + FS of Tebuconazole (0.1%), T_2: ST with Vitavax power (0.3%) + FS of Hexaconazole (0.1%), T_3: ST with Vitavax power (0.3%) + FS of Penconazole (0.1%), T_4: ST with Vitavax power @ 0.3% + FS of Propiconazole (0.1%), T_5: ST with Vitavax power (0.3%) + FS of Tridemorph (0.1%), T_6: ST with Vitavax power (0.3%) + FS of Copper oxychloride (0.3%), T_7: ST with Vitavax power (0.3%) + FS of Ziram (0.2%), T_8: ST with Vitavax power (0.3%) + FS of (Hexaconazole 4% + Zineb 68% WP) Avtar (0.2%)and T_9: Untreated control. The treatment sprays given at 65, 85 and 105 DAS. General spays of Streptomycin sulphate (500 ppm) was sprayed four times in order to prevent the infection of bacterial blight. Besides, the crop was also sprayed with Acetamiprid 20 SP and Imidacloprid 17.8 SL thrice to manage sucking pest infestation. The disease (PDI) was recorded at 120 DAS. Five plants in each plot were scored for disease and data has been converted into per cent disease index (PDI). The observations yield and fibre quality were also recorded. The economic analysis of this experiment has been worked out. The observations on disease intensity was recorded by using 0 - 4 scale and then these grades were converted into per cent disease indices (PDI) by using the formula given by Wheeler (1969) and finally per cent disease control was calculated. The yield cotton produce of each treatment was picked separately as and when the bolls opened and collected in cloth bags. Seed lint yields of net plot were recorded (kg/ha). The data obtained in the experiment was statistically analysed following the procedure given by Panse and Sukhatme (1985).

RESULTS AND DISCUSSION

Five systemic fungicides, two non systemic fungicide and one combi product fungicides were used as foliar spray and one combi product fungicide commonaly used as seed dresing fungicide in all the treatment were evaluated along with untreated control under natural field conditions, during *kharif,* 2010-2011 and 2011-2012. The results of pooled data are presented.

The results of 2010-2011 revealed (Table 2) that ST with Vitavax power (0.3%) + FS with Propiconazole (0.1%) significantly lowered Alternaria leaf spot per cent disease index (6.34 PDI) which was *on par* with ST with Vitavax power (0.3%) + FS with Tebuconazole (0.1%) (7.71 PDI) followed by ST with Vitavax power (0.3%) + FS with Hexaconazole (0.1%) (9.73 PDI) while ST with Vitavax power (0.3%) + FS with Ziram (0.2%) (13.10 PDI) was the least effective. The eight treatments of fungicides tested significantly reduced the per cent disease index over control. Maximum per cent disease control (PDC) recorded in case ST with Vitavax power (0.3%) + FS with Propiconazole (0.1%) (82.14 PDC) followed by ST of Vitavax power (0.3%) + FS with Tebuconazole (0.1%) (78.28 PDC) and ST with Vitavax power (0.3%) + FS with Hexaconazole (0.1%) (72.59PDC), respectively. Significantly maximum average bolls/plant was recorded in case ST with Vitavax power (0.3%) + FS with Propiconazole (0.1%) (29.49) which was *on par* with ST with Vitavax power (0.3%) + FS with Copper oxychloride (0.3%) (28.60) followed by ST with Vitavax power (0.3%) + FS with Tebuconazole (0.1%) (28.00), respectively.

The *kapas* yield variation among the treatments was non significant. However, the maximum yield of 2714.35 kg/ha was recorded in ST with Vitavax power (0.3%) + FS with Propiconazole (0.1%) followed by ST with Vitavax power (0.3%) + FS with Tebuconazole (0.1%) (2615.43 kg/ha) and ST with Vitavax power (0.3%) + FS with Hexaconazole (0.1%) (2529.48 kg/ha). Among the fibre quality parameters, the statistically *on par* between the treatments and un treated control in all the parameters (Table 1).

The results of 2011-2012 revealed (Table 2) that ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) significantly lowered disease index (4.74 PDI) which was *on par* with ST with Vitavax power (0.3%) + FS of Tebuconazole (0.1%) (6.12 PDI) followed by ST with Vitavax power (0.3%) + FS of Hexaconazole (0.1%) (7.21 PDI) while ST with Vitavax power (0.3%) + FS of Ziram (0.2%) (10.41 PDI) was the least effective. All the treatments significantly reduced per cent disease index over control. Maximum per cent disease control (PDC) recorded in case ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) (85.42 PDC) followed by ST with Vitavax power (0.3%) + FS of Tebuconazole (0.1%) (81.18 PDC) and ST with Vitavax power (0.3%) + FS of Hexaconazole (0.1%) (77.82PDC), respectively. Significantly maximum average bolls/plant was recorded in case ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) (31.87) which was *on par* with ST with Vitavax power (0.3%) + FS of Tebuconazole (0.1%) (30.47) and ST with Vitavax power (0.3%) + FS of Copper oxychloride (0.3%) (29.87) followed by ST with Vitavax power (0.3%) + FS of Hexaconazole (0.1%) (28.20), respectively.

The *kapas* yield variation among the treatments was non significant. However, the maximum yield of 2840.42 kg/ha was recorded in ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) followed by ST with Vitavax

Table 1. Field efficacy of fungicides on fibre quality parameters of *Bt* cotton (*kharif* 2010-2011 and 2011-2012)

Tr. No.	2.5 per cent SL (mm)		UR (%)		Micronaire value		Tenacity (g/t)		Elongation		SL ratio	
	2010-2011	2011-2012	2010-2011	2011-2012	2010-2011	2011-2012	2010-2011	2011-2012	2010-2011	2011-2012	2010-2011	2011-2012
T_1	32.60	32.33	46.00	45.67	4.17	3.93	22.27	22.70	5.83	5.87	0.68	0.70
T_2	32.13	32.13	47.67	46.67	4.23	4.07	23.17	22.33	5.80	5.83	0.72	0.70
T_3	32.00	32.27	46.67	46.67	4.17	4.10	22.93	22.23	5.73	5.97	0.72	0.69
T_4	31.57	32.47	46.67	46.33	4.37	4.20	22.30	22.03	5.77	5.90	0.71	0.68
T_5	31.53	31.83	47.00	46.33	4.27	3.87	23.30	23.70	5.93	5.83	0.74	0.74
T_6	31.77	31.70	47.00	46.33	4.17	4.17	22.97	22.37	5.83	6.00	0.72	0.71
T_7	32.13	32.40	47.00	46.33	4.03	3.93	23.30	22.63	5.83	5.93	0.73	0.70
T_8	31.83	32.20	47.00	46.33	4.17	4.13	23.43	22.30	5.80	5.93	0.74	0.69
T_9	31.67	32.17	46.67	46.67	4.30	4.00	22.53	22.87	5.83	5.93	0.71	0.71
p=0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
SEm±	0.23	0.42	0.53	0.55	0.07	0.09	0.42	0.35	0.06	0.07	0.01	0.02

power (0.3%) + FS of Tebuconazole (0.1%) (2756.17 kg/ha) and ST with Vitavax power (0.3%) + FS of Penconazole (0.1%) (2615.25 kg/ha). Among the fiber quality parameters, the statistically *on par* between the treatments and untreated control in all the parameters (Table 1).

The results of pooled data revealed (Table 2) that the ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) significantly lowered disease index (5.54 PDI) which was *on par* with ST with Vitavax power (0.3%) + FS of Tebuconazole (0.1%) (6.92 PDI) followed by ST with Vitavax power (0.3%) + FS of Hexaconazole (0.1%) (8.47 PDI) while ST with Vitavax power (0.3%) + FS of Ziram (0.2%) (11.76 PDI) was the least effective. All the treatments reduced per cent disease index over control. Maximum per cent disease control (PDC) recorded in case ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) (83.71 PDC) followed by ST with Vitavax power (0.3%) + FS of Tebuconazole (0.1%) (79.66 PDC) and ST with Vitavax power (0.3%) + FS of Hexaconazole (0.1%) (75.09 PDC) respectively. Significantly maximum pooled average bolls/plant recorded in case ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) (30.68) which was *on par* with ST with Vitavax power (0.3%) + FS of Tebuconazole (0.1%) (29.23) and ST with Vitavax power (0.3%) + FS of Copper oxychloride (0.3%) (29.23) followed by ST with Vitavax power (0.3%) + FS of (Avtar) Hexaconazole (4%) + Zineb (68% WP), (0.2%) (27.67), respectively.

The pooled *kapas* yield variation among the treatments was significant. However, the maximum yield of 2777.39 kg/ha was recorded in ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) which was *on par* with ST with Vitavax power (0.3%) + FS of Tebuconazole (0.1%) (2685.80 kg/ha) and ST with Vitavax power (0.3%) + FS of Hexaconazole (0.1%) (2554.02 kg/ha) (Table 2).

Shtienberg and Dreishpoun (1991) reported that Difenoconazole @ 0.125 kg a.i./ha and Tebuconazole at 0.187 kg a.i./ha suppressed Alternaria leaf spot to a significant extent as compared to untreated plots and differences in yield of 15.6-39.0 per cent increase were in treated than the untreated plots. Chattannavar *et al.,* (2004) observed that the new chemical Folicur (Tebuconazole) at 0.05 and 0.07 per cent was very effective against Alternaria blight and grey mildew followed by Copper oxychloride. Folicur at 0.05 per cent and 0.07 per cent recorded the highest cotton yield (1586.92 and 1630.65 kg/ha, respectively) compared to 1041.66 kg/ha in untreated control.

Economics of chemicals fungicides : The economics of cost benefit ratio has been worked out for different fungicides and are presented in Table 3. The highest total returns were obtained by ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) (Rs. 111095) followed ST with Vitavax power (0.3%) + FS of Tebuconazole (0.1%) (Rs.107432). Similarly net returns and additional net returns over control were also high in ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) (Rs. 70313 and Rs. 26576.45, respectively) than any other fungicides. ST with Vitavax power (0.3%) + FS of Hexaconazole recorded Rs. 63556 of net returns and Rs. 19819 of additional net returns over control. However, when incremental

Table 2. Field efficacy of fungicides on incidence of Alternaria leaf spot, control and yield of *Bt* cotton (pooled data of *kharif* 2010-2011 and 2011-2012)

Tr. No.	PDI			PDC	Average bolls /plant			Yield (kg/ha)		
	2010-2011	2011-2012	**Pooled**		2010-2011	2011-2012	**Pooled**	2010-11	2011-12	Pooled
T_1	7.71(16.14)*	6.12(14.30)	**6.92(15.22)**	79.66	28.00	30.47	**29.23**	2615.43	2756.17	**2685.80**
T_2	9.73(18.13)	7.21(15.59)	**8.47(16.86)**	75.09	26.73	28.20	**27.47**	2529.48	2578.56	**2554.02**
T_3	10.32(18.75)	7.83(16.23)	**9.08(17.49)**	73.31	26.00	27.93	**26.97**	2456.22	2615.25	**2535.73**
T_4	6.34(14.58)	4.74(12.52)	**5.54(13.55)**	83.71	29.49	31.87	**30.68**	2714.35	2840.42	**2777.39**
T_5	11.11(19.48)	8.62(17.02)	**9.87(18.25)**	70.99	25.53	27.27	**26.40**	2431.79	2473.53	**2452.66**
T_6	10.08(18.41)	8.33(16.79)	**9.21(17.60)**	72.93	28.60	29.87	**29.23**	2511.88	2572.36	**2542.12**
T_7	13.10(21.10)	10.41(18.82)	**11.76(19.96)**	65.43	25.13	27.13	**26.13**	2418.36	2482.85	**2450.61**
T_8	9.85(18.28)	7.43(15.83)	**8.64(17.05)**	74.59	27.47	27.87	**27.67**	2483.64	2540.86	**2512.25**
T_9	35.50(36.57)	32.51(34.75)	**34.01(35.66)**	79.66	23.47	24.60	**24.03**	1912.35	2015.50	**1963.92**
p=0.05	2.50	2.37	**1.54**	-	3.24	3.21	**2.28**	338.09	397.64	**226.89**
SEm±	0.83	0.79	**0.51**		1.08	1.07	**0.76**	112.77	132.64	**75.68**

* Figures in parentheses indicate angular transformed values

Table 3. An economic analysis of fungicides against Alternaria leaf spot of *Bt* cotton under field condition

Tr. No.	Treatment	Cost of chemical (Rs/1/kg)	Qty required/ ha in 3 spray (ml/g)	Total cost of chemical/ ha in 3 spray (Rs)	Cost of culti-vation (Rs)	Total cost (Rs.)	Additi-onal cost over control (Rs.)	Yield (kg/ha)	Total returns (Rs)**	Net returns (Rs)	Additional returns over control (Rs)	Incre-mental B:C
1	**2**	**3**	**4**	**5**	**6**	**7(5+6)**	**8**	**9**	**10**	**11(10-7)**	**12**	**13 (12/8)**
T_1	ST with Vitavax power* (0.3%) + FS of Tebuconazole (0.1%)	1644	1500	2477	38429	40906	6086	2686	107432	66526	22788	3.74
T_2	ST with Vitavax power (0.3%) + FS of Hexaconazole (0.1%)	549	1500	835	37770	38604	3785	2554	102160	63556	19819	5.24
T_3	ST with Vitavax power (0.3%) + FS of Penconazole (0.1%)	2228	1500	3353	37678	41031	6212	2535	101429	60397	16660	2.68
T_4	ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%)	1256	1500	1895	38886	40781	5962	2777	111095	70313	26576	4.46
T_5	ST with Vitavax power (0.3%) + FS of Tridemorph (0.1%)	1010	1500	1526	37263	38789	3969	2452	98106	59317	15579	3.92
T_6	ST with Vitavax power (0.3%) + FS of COC (0.3%)	450	4500	2036	37710	39747	4927	2542	101684	61938	18201	3.69
T_7	ST with Vitavax power (0.3%) + FS of Ziram (0.2%)	230	3000	701	37253	37954	3134	2450	98024	60070	16333	5.21
T_8	ST with Vitavax power (0.3%) + FS of Avtar (0.2%)	1335	3000	4016	37561	41577	6757	2512	100490	58912	15175	2.25
T_9	Control	-	-	-	34819	34819	-	1963	78556	43737	0	-

*Vitavax power seed dressing chemical cost Rs. 141/100 g, Required quantity 7.5 g/ha cost benefit ratio was calculated, ST with Vitavax power (0.3%) + FS of Hexaconazole (1: 5.24) proved better because of low cost of the chemical than ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) (1: 4.46).

However from the farmers point of view, the economics of disease management is important. In the present investigation the ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) has given highest total returns, net returns and additional returns over control than any other fungicides. The ST with Vitavax power (0.3%) + FS of Tebuconazole (0.1%) were next in order with respect to all the three above mentioned parameters. However, the ST with Vitavax power (0.3%) + FS of Hexaconazole (0.1%) have recorded highest incremental benefit: cost of 5.24. The ST with Vitavax power (0.3%) + FS of Propiconazole (0.1%) with 4.46 remained as next best fungicide. This is because, Propiconazole is costlier than Hexaconazole.

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Evaluation of cotton genotypes against grey mildew and rust diseases

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ABSTRACT: Two hundred and ninety three cotton genotypes were screened for grey mildew disease and 442 genotypes were screened against rust disease during *kharif,* 2003 to 2010 under natural epiphytotic conditions. Forty six entries were free from grey mildew and 43 genotypes recorded resistant reaction. Three entries were free from rust and 17 genotypes recorded resistant reaction. The entry TCS 1734 was free from grey mildew during two consecutive years; GSHV 97/612 and JKCH 55 were resistant; and CPD 787, NDLH 1938 and CCB 5 showed moderate resistance. Two entries, JKCH 55 and GSHV 97/612 showed moderately resistant reaction to rust. One entry LH 2152 was free from both grey mildew rust while GJSV 374 was moderately resistant to both diseases.

Keywords: Cotton, evaluation, grey mildew, rust

Cotton crop is known to suffer from a number of foliar diseases caused by fungi, bacteria and viruses. During recent years, grey mildew (*Ramularia areola* Atk.) and rust (*Phakospora gossypii* (Arth.) Hirat.f.) diseases attained major status causing losses to the tune of 30 to 40 per cent. Four foliar sprays with 0.1% carbendazim during 50 to 95 days after sowing at 15 days intervals significantly reduced disease intensity from 34.75 to 11.89 per cent and prevented losses up to 31.3 per cent. Protection with propiconazole (0.1 %) from 75 to 120 DAS against rust disease significantly reduced disease intensity from 41.14 to 16.7 per cent and prevented losses upto 36.67 per cent. Growing disease resistant variety / hybrid helps to minimize losses caused by these two important diseases. This strategy is eco friendly and farmer friendly as it reduces the financial burden of small and marginal farmers, in particular, tenant farmers. Hence identification of disease resistant genotypes is essential for developing resistant cultivars. With this objective the present investigation was taken up under coordinated programme.

MATERIALS AND METHODS

Two hundred and ninety three cotton genotypes were screened for grey mildew disease and 442 genotypes were screened against rust during *kharif,* 2003-2010. All the material was received under All India Coordinated Cotton Improvement Programme and sown on 11.07.2003, 19.07.2004, 27.07.2005, 05.08.2006, 20.07.2007, 14.07.2008, 19.08.2009 and 14.07.2010. Each entry was sown with a spacing of 120 x 60 cm and 10 hills/row and replicated twice. Susceptible check LRA 5166 was sown after every four rows and also as border of two rows around the experiment. Plants at random were tagged from each line and 10 leaves (lower and middle) from each plant were scored for disease intensity adopting 0 to 4scale: 0 = No disease; 1 = (<5%); 2 = (6-20%); 3 = (20-40%) and 4 = (>40%) leaf area diseased. Scoring was done at 90 and 120 DAS under natural conditions. Depending on the scores recorded per cent disease intensity (PDI) was calculated by using the formula of Wheeler (1969).

$$\text{PDI} = \frac{\text{Sum of numerical ratings}}{\text{Number of plants infected x maximum rating}} \times 100$$

Depending upon the grade of infection, germplasm was classified into immune, resistant, moderately resistant, moderately susceptible and susceptible lines.

RESULTS AND DISCUSSION

Pooled data for grey mildew reaction for six years showed that among 293 genotypes screened no infection was recorded on 46 entries recorded and 43 genotypes expressed resistant reaction while 60 expressed moderately resistant reaction against grey mildew disease. Forty four entries recorded moderately susceptible reaction and 100 genotypes were susceptible to grey mildew (Table 1). Genotypes under *Gossypium barbadense* recorded resistance reaction. Earlier Dake and Kannan (1982) reported *G. barbadense* varieties ERB 4492, Sujatha, Suvin and SB 289 E were resistant to grey mildew. Sixteen genotypes exhibited a high level of resistance and 58 showed resistant reactions to *R. areola* during field screening of 1000 world collections of cotton germplasm (Lakshmanan and Vidyasekaran (1990). Mohan *et al.,* (2001) evaluated 1489 germplasm lines and reported seven immune lines namely, Bangladesh (EC 174092) and 0-135-49 belonging to race *bengalense* and 30805, 30814, 30826, 30838 and 30856 belonging to race *cernuum*. One *G. arboreum* genotype 30838 (INGR No. 02020) resistant to grey mildew have been registered with the NBPGR, New Delhi. Hosagoudar *et al.,* (2008) reported four moderately resistant reaction of non Bt genotypes to grey mildew during *kharif,* 2006. Chattannavar *et al.,* (2009) recorded 21 highly resistant and 35 moderately resistant genotypes against grey mildew during kharif 2007 and reported GSHV 97/612 as moderately resistant genotype. The entry TCS 1734 was free

Table 1. Grouping of cotton genotypes based on their reaction to grey mildew disease

Rating	Reaction	Genotypes
0	Immune (46)	TCS 1734, MR 68, TCH 1728, KH 1001, BS 37, ARBH 1001, P 2150, GJHV 500, CSH 3114, TCH 1717, H1472, RS 2596, LH 2152, BGDS 801, HS 288, GTHV 07/1, CSH 2810, CNH 1094, RHC 0717, CCH 820, ADB 531, L 770, SCS 793 , CPD 1002, CNH 1106, RAH 803, TSH 0250, GJHV 503, BS 39, ADB 532, F 2337, GSHV 158, H 1454, BS 279, GSB 39, DB 11, TCB 45, RAB 12, FHH 168, MRC 7361, DHH 1052, GTHH 191, BHH 12, TCHH 5150, RAJHH 787, HHH 490
1	Resistant (43)	ARBH 813, ZC (Sumangala), CCH 1831, GISV 103, GSHV 97/612, RAHH 246, ARCHH 9770, KDCHH 712, PSCHH 1037, JKCH 55, GJHV 476, HS 286, H 1454, TCH 1732, SCH 701, RAB 8, TCB 1, GSHV 159, RAH 216, CCB 1-1, RHCb 011, ARBHH 1052, LC (DHH 11), RAHH 255, RHH 0707, ABBH 1051, GSHH 2729, FHH 140, LHH 1403, ARBH 1052, XCH 7201, GTHH 193, MRC 7377, DHH 1051, BHH 16, GSHH 2361, RAJHH 790, RHH 0622, RAHH 455, SHH 451, HSHH 26, CSHG 3118, Sanjivani-021
2	Moderately) Resistant (60	CPD 787, Harita 225, PACHH 904, LMSH 15, CCCHH 04-1, RAJHHG 9, AKH 9620, GJSV 374, GJHV 502, CPD 2001, CPT 511, ARBH 2002, CA 101, RAH102, F 2177, RS 2557, CCH 818, TSH 9974, CISH-16, LH 2153, CSH 3158, CPD 2003, F 1861, ARBH 2004, NDLH 1939, LH 2139, RS 2569, BS 27, F 2228, RAH 336, TCH 1716, GSHV 155, SCS 415, BS 51, NDLH 1938, TCH 1715, ARBH 813, RAB 10, TCB 26, CCB 11, GSB 40, CCB 5, DB 12, Suvin (CC), DB 10, GSB 41, LH 2170, F 2276, GSHV 160, CPD 1001, RS 2620, SCS 792, CCH 10-1, ZC (LRA 5166), CCH 2623, TCH 26, RAHH 951, NSPL 423, RAHH 138, CSHH 4007
3	Moderately) Susceptible (44	CSH 2572, PUSA 734, F 2020, ARB 904, IH 07, CCH 1386, KH 151, BS 33, TSH 9704, ARB 760, CPD 755, KDCHH 1323, WGHH 2, Sandocot 645, Navkar 131, HHH 397, MRC 670, HHH 428, Ajeet 188, GCMSHH 72, CSHG 9, ARCHH 6158, HS 271, CPD 786, SSBH 17, CCH 1831, GISV 97016, CPD 814, P 403, NDLH 1839, GSHV 158, CCH 1212, KH 902, KH 901, BS 28, RAH 901, GISV 257, CSH 10, CCH 2623, BS 277, GISV 218, RHC 9854, HAGHH 2064, ARCHHH 7256
4	Susceptible (100)	AKH 9620, HS 271, CNH 012, RS 2367, SCS 1023, Narasimha, ADB 321, CSH 4299, TCH 1608, H 1282, TSH 9701, GSHV 01/1338, L 789, LH 2040, GSHV 97/1092, RHC 2023, RAH 226, CPD 803, CCH 317, RB 533, CCH 510-4, KH 140, TSH 9725, ADB 250, GSHV 99/291, F2036, L 604 (LC), Surabhi (ZC), GSHV97/6/2, H 1250, ARB 2001, Indam 178, RAHH 168, MRC 6315, LAHH 5(LC), SHH 56, Tulasi 4, Nimbakar 1110, ZCH 21405, HAGHH 409, PRCH 243, VBCH 2204, PSCHH 550, DHH 404, ARCHH 754, DMSHH 176, MRC 6303, Mahabeej 207, Bunny (ZC), Daftari 141, PSCHH 213, RCH 138, GSGHH 52, DMSHH 276, PCHH 104, NCHH 45, CSHG 26, LAMCH 6, LRCH 1705, NRCH 1705, GOPAL 401, LMSH 50, ARBMSHH 440, LAMCH 5, HAGMSHH 439, HHH 399, Sandocot 1003, MCH 10, Uday 444, CSH 2572, CCH 510, GK 154, PMCH- 99, Tulasi 117, VCH 150, PSCHH 213 , GISV 103, ADL 903, NDL 762, LH 2076, LC 761, P72-9-37, GSHV 97612, HAG 1055, GSHV 011338, CPD 755, ARB 760, PCHH 78, SSB 3, JKCH 2022, ZC (Dharwad), GK 150, Tulasi 27, NCHH 55, ARCHH 9770, RAH 216, RAH 61, BS 279, MR 786, GSHV 155

Table 2. Grouping of cotton genotypes based on their reaction to rust disease

Numerical Rating	Reaction	Genotypes
0	Immune (3)	LH 2153, LH 2152, RAJHH 787
1	Resistant (17)	RAH 216, GISV 103, CA 101, CPA 1001, CCH 820, SC7 92, BS 27, GJHV 502, CPD 2001, RAH 336, FHH 140, ARBH 1052, HHH 690, BHH 16, RAJHH 790, RHH 0622, SHH 451
2	Moderately Resistant (104)	GJHV 374, ARBH 813, CPD 812, H 1300, GSHV 97/612, RAHH 246, KDCHH 712, Tulasi 27, PSCHH 1037, JKCH 55, TSH 9908, RS 2525, TCH 1716, CPD 801, KH 140, F2168, CNH 1104, NDLH 1938, LH 2123, BS 51, CCH 2623, CSH 3129, CCH 4474, F2170, GISV 216, HS 283, RAH 336, RS 2527, BS 41, ZC (RS 2013), LH 2132, P 1752, Bihari 251, SCS 415, L 801, HAG 1015, GSHV 155, H 1360, CA 7, TCH 1715, CNDTS 55, NH 630, RAH 61, BS 277, CPD 1050, GISV 218, RHC 9854, BS 279, ARBH 225, CPD 1019, ARBH 813, P 57-6, RAH 216, CCB 5, CCB 6, TCB 108, RHCB 001, TCB 47, DB 1, CCB 1, GSB 41, ARBHH 51, RAHH 255, INDAM 1020, NSPL 423, CINHH 128, RAMSHH 7, TCHH-2, DHH 851, CINHH 129, RAJHH 743, HHH 455, LMSH 263, RHH 0523, HAGHH 2064, LHH 1350, JKCH 2516, ARCHH 7254, CSHG 2803, PHH 177, Tulasi 135, CSHH 1907, RAJHH 745, ARBHH 2040, RAHH 139, CSHH 1933, GSHH 2235, SHH 460, ARBHH 2036, RAHH 138, HHH 452, NSPL 999, FHH 168, DMSHH 856, MRC 7361, KDCHH 595, SHH 463, DHH 852, ZC (CSHH 198), ARBH 813, CPD 814, RAHH 246, KDCHH 712, PSCHH 1037
3	Moderately Susceptible (132)	ADB 320, F 2036, H 1246, GJHV 392, CCH 4, ARCHH 5642, PA 402, AKA 9503, AK 235 (ZC), MDL 2582, RS 2367, H 1282, IH 07, LH 2040, GSHV 97/1092, RAH 226, KH 151, TSH 9704, MRC 6315, KDCHH 1323, HAGHH 409, Sandocot 645, Daftari 141, RCH 138, PCHH 104, NRCH 1705, Ajeet 188, HAGMSHH 439, MCH 10, HS 271, AKH 9620, PD 755, VBCH 2204, GK 154, SSBH 17, PCHH 78, SHH 56, MRC 6303, NCHH 55, ARCHH 9770, PRCH243, BCHH 311, PSCHH 213, RCH 484, ADL 903, LH 2076, P72-9-37, GSHV 011338, ARCHH 9770, SSB 3, CSH 612, GJHH 448, MR 786, CPT 511, NDLH 1839, TSH 9974, CISH – 16, KH 902, SCS 701, KH 901, CSH 3158, CPD 2003, GISV 257, RS 2569, BS 27, CSH 10, F 2228, RAH 336, TCH 1716, BCS 415, NDLH 1938, TCH 1715, RAH 61, BS 279, ARBH 813, RAB 10, TCB 26, GSB 40, RAB 8, CCB 5, CCB 6, MR 68, TCH 1728, ARBH 1001, P 2150, GJHV 500, TCH 1717, GSHV 160, RS 2596, BGDS 801, GTHV 07/1, CSH 2810, CNH 1094, L 770, SCS 793, CPD 1002, CNH 1106, RAH 803, TSH 0250, ADB 532, GSHV 159, CCH 10-1, F 2337, GSHV 158, ZC (LRA 5166), BS 279, GISV 218, BS 51, GSB 39, RAB 8, RHCb 011, DB 11, TCB 45, RAB 12, CCB 5, ARBHH 1052, HAGHH 2064, LC (DHH 11), RHH 0707, FHH 168, LHH 1403, XCH 7201, GTHH 193, GTHH 191, BHH 12, TCHH 5150, MRC 7377, DHH 1051, RAHH 455, HSHH 26, CSHG 3118, Sanjivani-021
4	Susceptible (186)	Pusa 9217, NH 1020, LAM 787, TSH 9725, Surabhi (ZC), SCS 51, TCH 1390, GMR 5, CSH 35, RAH 3, RS 2357, CNH 3003, GSHV 99/307, LH 1995, L 604 (LC), HS 267, HAG 785, GSHV 99/291, CCH 510-4, RHC 1594, NDLH 761, ARB 784, ARB 2001, GSHV 97/6/2, ARB 760, CPD 755, TSH 9704, ADB 250, RAH 101, H 1250, ARB 2005, GSHV 97/13, ARB 9009, GJHV 370, CCH 526612, CPD 745, CCH 342, JKCH 10, NTHH 2001, BSSCH 244, Sandocot 708, RAHH 95, PSCH 504, PARAS 99, Haritha 225, Bunny(ZC), RAHH 95, Sumangala (VC), LAHH 5 (LC), Navkar 95, ARBMSHH 281, RCH 138, VCHH 1037, Aravinda (LC), Paig 8/1, RG 359, DLSA 56, LD 843, CINA 318, GAM 93, HD 427, RAS 2, KWA 142, LAS 2, MDL 2607, KWA 140, HD 407, LAS 4, DLSA 114, RG 277, Hirsutum check, Dlsa 201, Gam 107, Paig 127, PA 405, AK 235 (ZC), HD 424, AKH 9620, HS 271, CSH 2572, HAG 1055, PUSA 734, SCS 1023, F 2020, ADB 321, CSH 4299, TCH 1608, TSH 9701, ARB 904, GSHV 01/1338, L 789, NDL 762, RHC 2023, CCH 1386, CPD 803, CCH 317, BS 33, RB 533, CCH 510-4, TSH 9725, ADB 250, CPD 787, H 1250, CPD 755, Indam 178, SHH 56, Tulasi 4, Nimbakar 1110, ZCH 21405, WGHH 2, PRCH 243, VBCH 2204, PSCHH 550, DHH 404, ARCHH 754, DMSHH 176, Navkar 131, MRC 6303, Mahabeej 207, PSCHH 904, HHH 397, PSCHH 213, GSGHH 52, DMSHH 276, NCHH 45, MRC 670, CSHG 26, HHH 428, LMSH 15, GOPAL 401, LMSH 50, ARBMSHH 440, GCMSHH 72, CCCHH 04-1, LAMCH 5, CSHG 9, HHH 399, RAJHHG 9, Sandocot 1003, ARCHH 6158, Uday 444, CNH 012, CSH 2572, LC (NA 1325), KH 140, CCH 510, PMCH- 99, RAHH 22, DAFTHARI – 141, Tulasi 117, RAHH 168, VCH 150, GISV 103, CCH 1831, GISV 97016, CPD 814, LC 761, CCH 510, GSHV 97612, RS 2557, GSHV 155, BS 277, RHC 9854, CCB 11, LH 2570, F 1861, CA 107, H 1462, HS 288, RS 2620, BS 39, BS 277, GSHV 155, CCH 2623, CCB 1-1, DB 12, TCH 26, RAHH 951, NSPL 423, RAHH 138, RAHH 255, GSHH 2729, ARCHH 7256, MRC 7361, CSHH 4007, DHH 1052

from grey mildew during two consecutive years; GSHV 97/612 and JKCH 55 were resistant; and CPD 787, NDLH 1938 and CCB 5 showed moderate resistance to grey mildew during two years of testing at Guntur.

Among 442 genotypes screened during 2003 to 2010 revealed that three entries viz., LH 2153, LH 2152, RAJHH 787 were free from rust infection, 17 genotypes recorded resistant reaction while 104 expressed moderately resistant reaction against rust disease (Table 2). One hundred and thirty two entries recorded moderately susceptible reaction and 186 genotypes were susceptible to rust disease. Chattannavar and Hosagoudar (2009a) screened 190 genotypes during *kharif,* 2007 and reported moderately resistant reaction of JKCH55. At Guntur JKCH 55 and GSHV 97/612 showed moderately resistant reaction to rust disease.

One entry LH 2152 was free from both grey mildew rust diseases while GJSV 374 was moderately resistant to both diseases.

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Diversity and antibacterial activity of actinobacteria isolated from cotton fields in semi arid zones of Haryana

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ABSTRACT : This study was undertaken to isolate actinobacteria from the rhizospheric soils collected from different cotton growing under semi arid zones of Haryana. In total, 18 different morphotypes of actinobacteria were isolated and purified on Kenknight medium. The amplified ribosomal DNA restriction analysis (ARDRA) of these isolates by using three restriction enzymes *Hae*III, *Msp*I and *Alu*I showed wide diversity among different isolates. Except for one isolate K7, all other isolates cluster in the major group II at 51 per cent similarity coefficient indicating that K7 is distinct from all the other isolates at the molecular level. The major group II was further divided into 8 sub groups at 90 per cent similarity coefficient, further confirming considerable genetic diversity among its members. These isolates were also assessed for their antibacterial activity against five pathogenic strains *viz. E.coli, Bacillus subtilis, Staphylococcus aureus, Agrobacterium tumefaciens, Pseudomonas aeruginosa* and found to be of potential antagonists against pathogens.

Key words: Antibiotics, antibacterial activity, actinobacteria, kenknight medium, secondary metabolites,

Haryana is a small north Indian state which falls under semi arid zone. Actinobacteria are the major groups of the soil microflora. These microorganisms have characteristics common to both bacteria and fungi and yet possess sufficient distinctive features to classify them into a separate category. Actinobacteria produce slender, branched filaments that develop into a mycelium. The filament may be long or short, depending on the species. They form an aerial mycelium, much smaller than that of fungi and many species produce asexual spores called conidia. In abundance, actinobacteria are second to bacteria in soil. The resemblance of actinobacteria to bacteria is because the actinobacterial species contain peptidoglycan in their cell walls and possess flagella similar to that of bacterial flagella. In addition, actinobacteria are sensitive to antibacterial antibiotics and not antifungal antibiotics. They are widespread in nature and found to be more in dry than wet soils. In actinobacteria (Gram positive bacteria with a high G + C content), the genera *Streptomyces*, *Rhodococcus*, *Corynebacterium*, and *Mycobacterium* have received an increasing amount of attention, particularly in the industrial fields. They exhibit potential advantages in the synthesis of secondary metabolites of industrial and medical importance in the production of amino acids by fermentation and in bioconversion processes (Nakashima *et al.*, 2005). Further, they can produce an array of secondary metabolites, many of which have antibacterial or antifungal properties. Infact, most antibiotics developed for human pharmaceutical uses are actinomycetes metabolites, many of them being derived from *Streptomyces* sp. *Streptomyces* are widely used in industries due to their ability to produce numerous chemical compounds including antibiotics, enzymes and anti-tumor agents or may function as herbicides (Poornima and Ponmurugan, 2006). The most promising role for secondary metabolites relies upon defense mechanisms. Inhibiting other, competing cells, would leave more nutrients for the survival of the secondary metabolites producing strain.

One of the aims of biodiversity studies of actinobacteria is to use effective isolation procedures to study the distribution of actinobacteria in various climatic and ecological environments. The isolation of diverse and novel cultures of actinobacteria provide a theoretical guide for the exploitation and utilization of actinobacterial resources. Most of the actinobacteria have clinical applications on the basis of their activity against different kinds of microorganisms *viz.*, antibacterial, antiparasitic and antiviral. In the present study, diversity of actinobacteria was studied in the cotton fields from different agro ecological zones of Haryana in order to identify specific populations of actinobacteria having antibacterial activity which are dominating under stress conditions.

MATERIALS AND METHODS

Sample collection and chemical analysis : Soil samples were collected from cotton rhizospheres growing under semi arid zones of Haryana. These samples were obtained at a depth of 6-10 cm in the rhizosphere regions of crops. The soil samples were allowed to air dry at room temperature and various parameters like soil pH, organic carbon, total nitrogen and available phosphorous were determined subsequently.

Isolation, enumeration and biochemical characterization of actinomycetes isolates : Isolation and enumeration of actinomycetes present in these soil samples was performed by serial dilution plate technique using KenKnight medium supplemented with ampicillin 25ìg/ml. Ten g of each sample was taken in 90 ml of sterile water. The flasks were kept on a shaker for half an h. From these flasks 1 ml sample was taken and diluted with 9 ml of sterile distilled water in 6 culture tubes to get/10^{-1} to 10^{-5} concentration of original sample. Then the last 3 dilutions were plated on petridishes having Kenknight medium. All plates were kept at 37^0C in the incubator and observed for growth every day. After 5 days, in each plate was observed few actinomycetes colonies out of which, 18 isolates of actinobacteria were isolated and purified on Kenknight medium. These isolates were pigmented, spore forming, Gram positive filaments. Biochemical characterization such as pigment production, starch hydrolysis, casein hydrolysis, catalase test, nitrate reduction, indole production and hydrogen sulphide production were also carried out.

Genomic DNA extraction and RFLP of the amplified product : Genomic DNA of the selected 18 isolates was extracted by CTAB method. DNA was amplified using actinobacterial primers. These primers were 333F (5'-TCC AGGCCC TAC GGG -3') and 1378R (5'- CGG TGT GTA CAA GGC CCG GGA ACG - 3'). The PCR mixture (24ìl) contained 2.5 ìl of 10Xbuffer, 0.5 ìl of 10 mM deoxynucleoside triphosphates (dNTPs), 0.5 ìl of $MgCl_2$ (25 mM), 20 pmol (1 ìl) of each primer, 0.5 ìl of *Taq* polymerase, and 50 ng (1 ìl) of DNA. The PCR was run at the conditions of 94°C for 2 min, 94°C for 45 s, 52°C for 45 s, and 72°C for 1 min for 35 cycles, followed by 72°C for 20 min. The amplified product was subjected to restriction digestion with three restriction enzymes *Hae* III, *Msp* I and *Alu* I. The band patterns obtained (genomic profile) were used to

Table 1. Detailed description of the isolates obtained from Kenknight medium

Sr. No.	Name	Soil sample	Village	Gram stain	Colour of spore/ colony	Amplification with 16S rRNA gene primers (333a/ 1378R)
1	K1	22	Bawal	G +ve filaments	off white	+
2	K2	1	Nalwa	G +ve filaments and spores	Pink	+
3	K3	9	Akoda	G +ve filaments	Henna	+
4	K4	9	Akoda	G +ve filaments	Light brown	+
5	K5	1	Nalwa	G +ve filaments	Off white	+
6	K6	9	Akoda	G +ve filaments	Off white	+
7	K7	5	Dadri	G +ve short rods	No pigment	+
8	K8	9	Akoda	G +ve filaments	Light green	+
9	K9	9	Akoda	G +ve filaments	Dark brown	+
10	K10	9	Akoda	G +ve filaments and spores	Green	+
11	K11	5	Dadri	G +ve filaments	White	+
12	K12	1	Nalwa	G +ve filaments	Light brown	+
13	K13	1	Nalwa	G +ve filaments	Light brown	+
14	K14	5	Dadri	G +ve filaments	Diffused green	+
15	K15	1	Nalwa	G +ve filaments	Henna	+
16	K16	5	Dadri	G +ve filaments	Brown	+
17	K17	9	Akoda	G +ve filaments	Light green	+
18	K18	9	Akoda	G +ve filaments	Light green	+

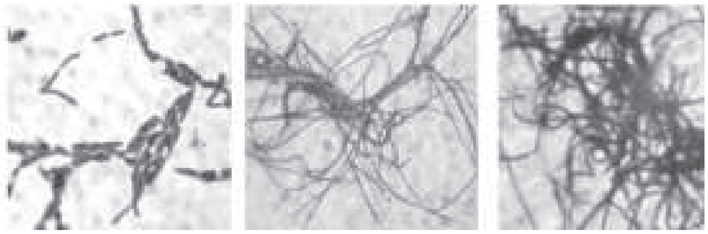

Fig. 1. Gram staining of selected isolates. The photograph shows gram +ve rods K7(A) and gram +ve filamentous bacteria K3(B) and K12(C).

generate a data matrix and a dendrogram was then constructed through the unweighted pair group method with arithmetic averages (UPGMA) using the NTSYS-pc program to determine the diversity of actinobacteria.

Screening for antibacterial activity : For the screening of antibacterial activity, the pure cultures of actinomycetes strains were inoculated into 100 ml of TY broth taken in a 250 ml of conical flask. The flasks were kept on a shaker at 220 rpm for 10 days. The broth cultures were centrifuged at 10,000 rpm for 10 min and supernatant was tested for antibacterial activity against *E.coli*, *Bacillus subtilis, Staphylococcus aureus, Agrobacterium tumefaciens, Pseudomonas aeruginosa* by standard well diffusion method. For these, wells were punctured in fresh test microbial lawn cultures on Nutrient agar medium by using a sterile cork borer. The supernatant culture broths were then administered to fullness in each well. The plates were incubated at 37^{0}C for 24 h and zone of inhibition was observed.

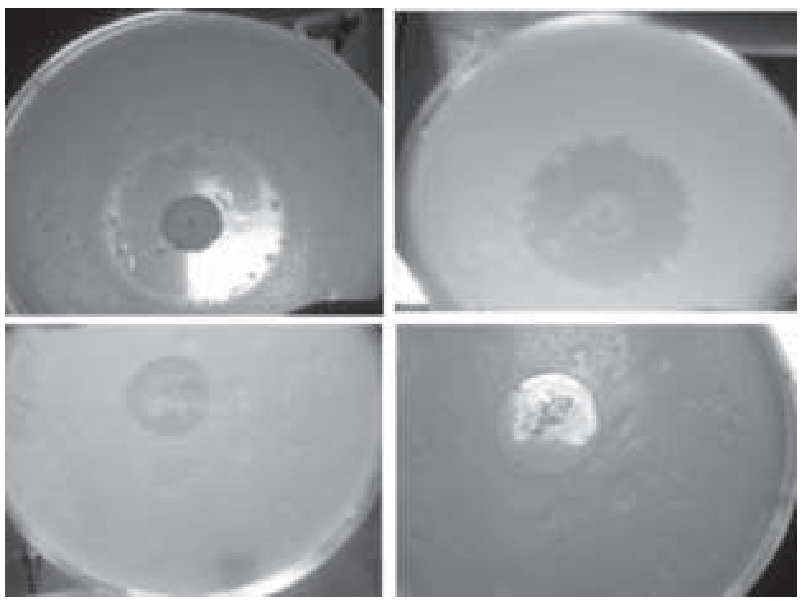

Fig. 2. Antibacterial activity of the actinomycetes isolates K2, K6, K10 and K12 against *P. aeruginosa, S .aureus, A. tumefaciens* by well diffusion method. Zone of inhibition shown by the isolates K2, K6, K10 and K12.

RESULTS AND DISCUSSION

Actinobacteria are nutritionally versatile microorganisms being able to grow both on rich substrates and on those containing a minimum or even an apparent lack of nutrients. In the present investigation, total eighteen isolates of actinobacteria were isolated and purified on Kenknight medium. These isolates were subjected to study their morphological physiological and biochemical characteristics. All the actinomycetes isolates showed good sporulation with compact, chalk like dry colonies of different colony variation from pink to off white

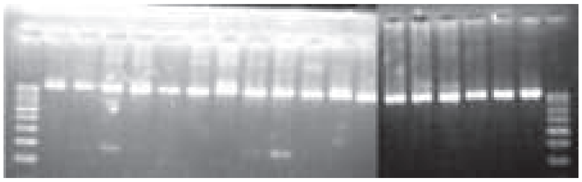

Fig 3. Amplification of 16S rDNA in actinobacterial isolate

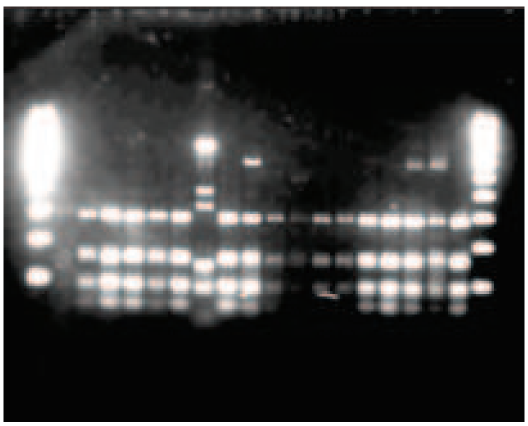

Fig 4. Restriction patterns obtained with enzyme *Msp*I

colour. Based on the morphological, physiological and biochemical characteristics, the purified isolates of actinomycetes belonged to *Streptomyces* sp (Table 1 and 2). All the isolates were found to be Gram positive organisms (Fig.1) and showed a branched mycelium in their cell morphology similar to fungal characters.

Genomic DNA was amplified using specific actinobacterial primers which amplified a product of 1070 bp (Fig. 3). For RFLP analysis of amplified product, three enzymes were used *Hae* III, *Msp* I and *Alu* I. (Fig. 4). The data from the restriction digestions was analyzed using the software NTSYS and dendrogram (Fig. 5) was prepared and showed diversity among eighteen isolates. Except for K7 and K9, all the isolates lie in the same major group but are parts of smaller subgroups with about 91 per cent similarity coefficient. The largest subgroup contains five isolates (K4, K5, K6, K15, and K18) which showed complete similarity to each other. Some biochemical tests were also performed and these isolates were then tested for antibacterial activity. The results of biochemical characterization indicated that pigment production was very well observed in most of the actinomycetes isolates. Most of the isolates were efficient in hydrolyzing starch and casein (Ravel *et al.*, 2000) except a few strains. Indole production was negative in isolates K3 and K6 but catalase was positive in all the isolates. Production of hydrogen sulphide, casein and starch hydrolysis showed a positive result in majority of the isolates. The results on the antimicrobial activity against standard pathogenic organisms showed that inhibition zone is formed around the pathogenic strains of *Bacillus subtilis, Pseudomonas aeruginosa* and *Agrobacterium tumefaciens* (Fig 2). The formation of inhibition zone around the pathogenic strains is due to the production of secondary metabolites by actinobacteria. Actinobacteria are the major antibiotic producers in the pharmaceutical industry (Vasavada *et al.*, 2006; Dhanasekaran *et al.,* 2009). Although they have provided many important bioactive compounds of high commercial value, exploration of their biocatalytic potential is relatively a new phenomenon (Ramesh *et al.*, 2009). The reason for actinobacteria producing higher antibacterial activity towards gram negative bacteria in comparison to gram positive bacteria tested may be due to the cell wall of the gram negative

Table 2. Biochemical characterization of actinomycetes isolates

Parameters	Strains						
	K2	K3	K6	K10	K12	K15	K18
Gram reaction	+	+	+	+	+	+	+
Pigment production	+	+	“	+	+	+	+
Starch hydrolysis	+	+	+	+	+	+	+
Casein hydrolysis	+	+	+	+	+	+	+
Catalase test	+	+	+	+	+	+	+
Nitrate reduction	+	“	“	+	+	+	+
Indole production	+	“	“	+	+	+	+
Hydrogen sulphide	“	“	“	+	+	+	+

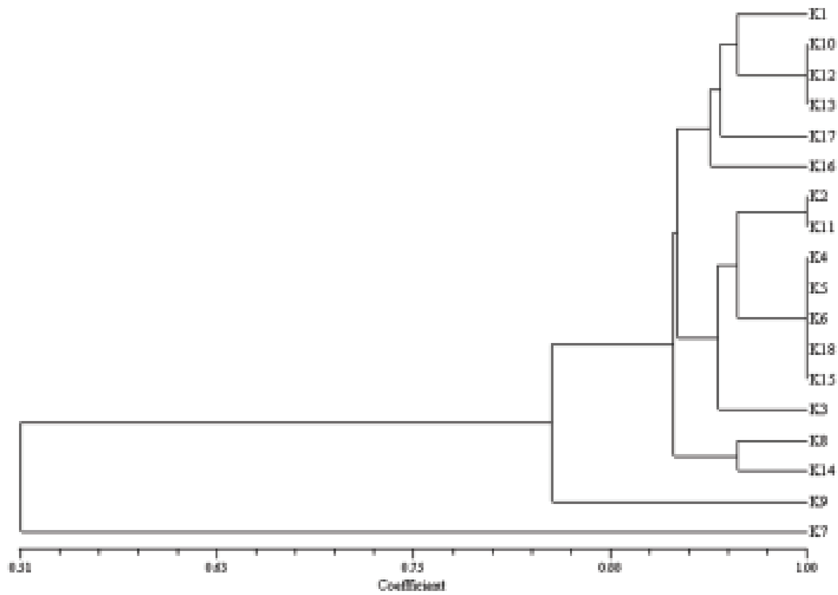

Fig. 5. Dendrogram depicting grouping of the actinobacterial isolates

bacteria is much easier to break than those of the gram positive. However this hypothesis does not concur with the finding by various researchers, where they observed that antagonistic reaction against the gram positive bacteria were much higher than the Gram negative (Basilio *et al.*, 2003; Oskay *et al.*, 2004; Sacramento *et al.*, 2004). In the present study, out of eighteen isolates of actinobacteria, 7 of the

Table 3. Antibacterial activity of selected strains against pathogenic bacteria

Sr. No	Cultures used	Actinomycetes isolates						
		K2	K3	K6	K10	K12	K15	K18
1	*Bacillus subtilis*	+	+	“	“	“	+	+
2	*Pseudomonas aeruginosa*	“	+	+	“	+	+	“
3	*Agrobacterium tumefaciens*	+	“	+	+	+	“	+
4	*Staphylococcus aureus*	“	“	“	“	“	“	“
5	*Escherichia coli*	“	“	“	“	“	“	“

strains K2, K3, K6, K10, K12, K15 and K18 were found to be potential antagonists against pathogens such as *Bacillus subtilis, Pseudomonas aeruginosa, Agrobacterium tumefaciens.* These strains were selected on the basis of their activity (clear zone produced) and K6 was found to be the most prominent secondary metabolite producer which produced largest clear zone.

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Threshold temperature and thermal constant for the development of cotton mealybug, *Phenacoccus solenopsis* (Tinsley) on cotton

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ABSTRACT : The effect of different constant temperatures, *i. e.* 20, 25, 30 and 35+ 1°C at 65 and 75 per cent R.H. was observed under laboratory conditions. The observations on development and survival of nymphs and adults of *P. solenopsis* revealed that the period of development was 43.00, 37.40, 35.00 and 31.00 days at 20, 25, 30 and 35+ 1°C and 65 per cent R.H., respectively. At 75 per cent R.H., however, it was 33.00, 35.40 34.40 and 31.60 days at above mentioned temperatures. The threshold temperature for nymph to adult, calculated by the method of mean temperature was 22.67 and 151.60°C at 65 and 75 per cent R.H., respectively. While the thermal constant for nymph to adult was calculated as 840.407 and 717.904 °D, respectively. The corresponding values for nymphal and adult stage were 57.33, 36.82 °C with 703.064 and 137.343 °D at 65 per cent R.H. However at 75 per cent R.H., it was 34.30, 82.43 °C with 180.725 and 537.179 °D.

Keywords: Cotton, day degrees, *Phenacoccus solenopsis*, thermal constant, threshold temperature

Cotton (*Gossypium* spp.) is a premier cash crop of India. With the introduction of *Bt* cotton, mealybug has emerged as major pest of cotton in the cotton belt of Punjab state and caused huge losses in seed cotton yield. According to Chong *et at.,* (2003) there is no development and survival as well as reproduction of *Phenacoccus maderiensis* on *chrysanthemum* when these were reared at 30-40°C. The day degree concept is based on the fact that there are minimum and maximum development threshold temperatures below or above which the organisms show either no development. Total heat energy required by an organism to complete different stages in a generation is constant despite temporal variations in temperature. With rise in temperature, days required for the development by a particular stage decreased and *vice versa* also hold good. Day degree concept is useful in the pest management as the development rate of an organism can be predicted more accurately by suing the heat units required as compared to the calendar days. Such information on *P. solenopsis* (Tinsley) in lacking in literature .Considering the importance of the pest and damaged caused to the cotton crop, the present study was undertaken to record heat unit requirements of nymphal and adult stage of this pest.

The present investigations on the effect of temperature on the stage of multiplication of *P. solenopsis* and day degree requirements were carried out in the B.O.D incubator at Department of Entomology, Punjab Agricultural University, Ludhiana during *kharif,* 2009. Insect culture was maintained on the potted cotton plants of variety RCH 134 in the inset searing screen cage.

In the laboratory, the mealybug was also reared on the cutting of tender parts of different hosts. These cuttings were replaced by new ones after every three days and mealybug population was shifted on new cuttings with the help of camel hair brush. Effect of four levels of temperature *viz.,* 20, 25, 30 and 35+ 1°C at 65 and 75 per cent R.H. on the development and survival of nymphal stage and longevity of *P. solenopsis* was studied in the B.O.D incubator in the laboratory using a chart of 50 freshly laid crawler of mealybug. Observations on the duration of nymphal and adult stages and their survival were recorded.

The adults were sexed on the basis of elongated body/abdomen in male and oval / broad and blunt abdomen in females. Observations on the fecundity and longevity of adults in case of all the temperature treatments were also recorded. The nymphs / crewless layed on petriplate were removed and contend. This procedure was continued till the female stopped laying crawls /or died.

The temperature threshold and the thermal constant were calculated by the mean temperature method using the following formula

$$K = n\,(T_1 - T_b)$$

Where; K= Thermal constant (°D), n= Duration of development (days), T= Temperature during the observation period (°C) and T_b = Threshold temperature (°C).Thermal constant of two different sets of conditions of temperature were equated to work out the threshold temperature.

$$K= n_1 (T_1-T_b) = n_2 (T_2-T_b) = n_3 (T_3-T_b)$$

Where ni = duration of development of each thermal level (1, 2, 3, 4), Ti = Average temperature of each level (1, 2, 3, 4) and T_b= Threshold temperature.

Effect of temperature on the biology of *P. solenopsis*

At 65 per cent R.H. : The mean duration of nymphal to adult stage of *P. solenopsis* was 43.00 days at 20±1°C (Table 1). The nymphal stage took 26.60 days while the adult stage was completed in 16.40 days. At 25±1°C, *P. solenopsis* took 37.40 days to complete its development from nymph to adult. The nymphal stage took 24.00 days while the adult stage took 13.40 days, respectively at 30±1°C. This pest completed its development from nymphal to adult in 35.0 days to compete its development. Whereas, the nymphal and adult stage took 21 and 14 days as their developmental period. The minimum development period i.e. 20.20 and 10.80 days was observed in nymphal and adult stages at 35±1°C, respectively and the total life span was completed in 31.00 days

At 75 per cent R.H.:- At 20±1°C, *P. solenopsis* completed its whole development in 33.00 days in which nymphs took 26.60 days and adults took 6.40 days, respectively. The nymphal adult period lasted for 25.00 and 10.40 days, respectively when observed at 25±1°C. Again the minimum development period was observed at 35±1°C as in case of 65 per cent R.H .The Total development period from nymph to adult was 31.60 days and the corresponding values for both the stages were 20.80 and 10.80 days , respectively.

The development from nymph to adult took 43.00, 37.40, 35.00 and 31.00 days at 65 per cent R.H. when the mean temperature was 20, 25, 30 and 35±1°C, respectively, Whereas, at 75 per cent RH the duration was 33.00, 35.40, 34.40 and 31.60 days corresponding to their mean temperature the development also affected accordingly, while the maximum development was observed at 35±1°C.

Threshold temperature and thermal constant : The above given basic information on the effect of different temperatures on the development of *P. solenopsis* provided the necessary sate for determining the threshold temperature and thermal constant at different combinations of temperatures. The above generated information was pooled to complete the average threshold temperature.

At 65 per cent R.H.

Nymphal stage: The threshold temperature for development of nymphs was 57.53 °C (Table 2) while the corresponding thermal constant value was 703.064°D. The per-stage observation of degree days was 998.298, 780.720, 578.130 and 455.106°D at 20°, 25°, 30°and 35+ 1°C temperatures, respectively.

Adult stage: The threshold of development for the adults of *P. solenopsis* was 36.82 °C (Table 2.) and the effective temperature above this threshold for the completion of adult stage was calculated as 137.343°D. The per stage thermal constant was very less as compared to nymphal stages. And the corresponding values were 275.848, 158.388, 95.480 and 19.656°D at their

Table 1. Average development periods of nymphs and adults of *P. solenopsis* under four constant temperatures at different relative humidities

Temperature (°C)	Duration (Days)					
	R.H. 65 per cent			R.H. 75 per cent		
	Nymph	Adult	Nymph to adult	Nymph	Adult	Nymph to adult
20±1	26.60(25-28)	16.40(16-17)	43.00	26.60(26-27)	6.40(6-7)	33.00
25±1	24.00(22-26)	13.40(12-15)	37.40	25.00(23-27)	10.40(10-11)	35.40
30±1	21.00(19-23)	14.00(12-16)	35.00	22.20(20-24)	12.20(11-13)	34.40
35±1	20.20(19-22)	10.80(9-12)	31.00	20.80(19-22)	10.80(9-12)	31.60

Figures in parentheses indicates range

respective mean temperatures (*i.e.* 20, 25, 30, 35+ 1°C) (Table 3).

Nymph to adult:- At favorable range of temperature between 25 and 35°C, the threshold of temperature for the development from nymphal to adult stage was 23.44, with the corresponding value for nymphal and adult stages being 170.26 and 16.54°C, respectively. The threshold temperature for the overall development of the insect from nymph to adult stage was 22.67°C (Table 2), while the corresponding value of thermal constant was 840.407°D (Table3). Among the two stages adult showed lowest heat requirements (137.343°D), whereas, nymphs have the highest heat requirements *i.e.* (703.064).

At 75 per cent R.H.

Nymphal stage: The threshold temperature for the development of nymph was lowest than the temperature required at 65 per cent R.H. *i.e.* 34.30 °C (Table2) with the thermal constant 180.725 °D. The per stage observation of degree days very less as that at 65 per cent R.H. the values for this was 380.380, 232.500, 95.460 and 14.560 at their respective temperature *viz.,* 20°, 25°, 30° and 35°C.

Adult stage: *P. solenopsis* adult completed its development at 82.43°C (Table 2.) threshold temperature, which was inverse to that of the temperature required at 65 per cent R.H. and the effective temperature above which adult completed its stage was calculated as 537.179°D (Table 3).

Table 2. Threshold temperature for nymphal and adult stage of *Phenacoccus solenopsis*

Stage	Rearing temperature (°C) levels at 65 per cent R.H.						Average threshold temperature (°C)
	20 and 25	20 and 30	20 and 35	25 and 30	25 and 35	30 and 35	
Nymph	26.15	15.18	27.34	10.00	170.26	96.25	57.53
Adult	2.33	38.33	8.93	141.67	16.54	13.12	36.82
Nymph to adult	13.39	23.75	18.75	47.92	23.44	8.75	22.67
	Rearing temperature (°C) levels at 75 per cent R.H.						
Nymph	58.13	30.45	33.79	14.64	24.52	44.29	34.30
Adult	35.50	41.03	55.56	58.89	295.00	8.57	82.43
Nymph to adult	93.75	265.71	318.57	147.00	58.16	26.43	151.60

Nymph to adult: At favorable range of temperature between 20 and 30°C, the threshold of temperature for the development from nymphal to adult stage was 265.71. The temperature °C for nymphal and adult stages being 30.45 and 41.03°C, respectively.The overall development of the insect from nymph to adult stage required 151.60°C threshold temperature (Table2) while the required thermal constant was 717.904°D (Table 3). Among the two stages, nymphal stage required only 180.725°D), whereas, the adult required highest heat requirements (537.179°D.

Not much literature was available on this aspect as most of the scientists used linear and nonlinear models to calculate the threshold temperature and thermal constant. So our finding did not matched with either of the studies conducted on these aspects, but they can be coated as the suited references for further studies. According to Iheagwam and Eluwa (2008) the durations of eggs, nymphs and immature adults of the cassava mealybug, *P. manihoti* Mat-Ferr. were determined at 3–4 constant temperatures. The duration of development of each stage decreased with increase in temperature. The rate of development was slowest in the egg and fastest in the second instar nymph. The calculated lower threshold temperatures were 14 °C (egg), 20 °C (instar I), 19 °C (instar II), 19.5 °C (instar III), 17 °C (immature adult), and 20 °C (egg adult). The sums of effective temperatures were for eggs, 131.4⁰D, instar I, 34.1⁰D, instar II, 33.0⁰D, instar III, 32.5⁰D, immature adult 58.5⁰D and egg mature adult 260.9⁰D above their respective thresholds. By fitting linear models to the data the lower developmental threshold temperatures for egg 1st nymphs, 2nd nymphs, 3rd nymphs, and egg 3rd nymph were calculated as 8.7, 12.8, 13.1, and 12.1 °C, respectively. The thermal constants were 198.6, 84.7, 69.8, and 296.3^{0}D, respectively, for each of the above stages. The non linear model based on a Gaussian equation used to predict relationship between development rate and temperature was well described for all stages. In addition, adult longevity decreased from 80.4 d at 16 °C to 31.3 d at 32.0 °C. Furthermore, the preoviposition and oviposition periods showed a pattern similar to that of longevity. Overall, *P. cryptus* had a maximum fecundity of 111 eggs/ female at 28 °C, which declined to 102.7 eggs/ female at 32 °C.

The present finding was in accordance with the studied conducted by Colen *et al.,* (2000) on the biology of the mealybug *Dysmicoccus brevipes* at four temperatures: 20, 25, 30 and 35°C, aiming at the determination of its thermal requirements as basic information for pineapple pest management programme. The inferior thermal threshold for development (base temperature) was 12.1; 13.5; 12.8 and 12.8°C for the 1st and 2nd instar nymphs, cocoon and nymphal periods, respectively. The thermal constants (K) for the nymphal phase of males was 393.4^{0}D and for females 605.6^{0}D. With the exception of the first instar, all the thermal constants obtained for females were superior to those determined for males.

Chong *et al.,* (2008) studied important life history parameters of the mealybug, *Maconellicoccus hirsutus* (Green), on hibiscus (*Hibiscus rosa-sinensis* L.) cuttings at six constant temperatures between 15 and 35°C. The development of *M. hirsutus* was the fastest at 27°C, where the mealybugs completed development in H"29 d. The lower (T_{min}) and upper (T_{max}) developmental thresholds and the optimal developmental temperature (T_{opt}) for the development of female mealybugs were estimated as 14.5, 35, and 29°C, respectively. The thermal constant (K), which is the number of temperature-day or ^{0}D units required for development, of the females was 347 DD. The original distribution range prediction (based on T_{min} = 17.5°C and K = 300 DD) indicated that *M. hirsutus* could complete at least one generation in all of the continental United States. However, results of this study suggested that the distribution range of *M. hirsutus* may expand northward because of the lower T_{min}, and the predicted number of generations in a year may be lower because of the higher K required to complete each generation. The average cumulative survival rate of *M. hirsutus* at 25 and 27°C was 72 per cent, which was significantly higher than 51 and 62 per cent at 20 and 30°C, respectively. Female

Table 3. Development periods, threshold temperatures and thermal constant for nymphs and adults of *P. solenopsis*

Relative humidity	Stage	Exposure temperature (°C)	Development period (Days)	Threshold temperature (°C)	Thermal constant(°D)	
					Per stage temperature	Average of stage
R.H. (65%)						
Nymph		20	26.60	57.53	998.298	**703.064**
		25	24.00	57.53	780.720	
		30	21.00	57.53	578.130	
		35	20.20	57.53	455.106	
Adult		20	16.40	36.82	275.848	**137.343**
		25	13.40	36.82	158.388	
		30	14.00	36.82	95.480	
		35	10.80	36.82	19.656	
	Nymph to adult					**840.407**
R. H. (75%)						
Nymph		20	26.60	34.30	380.380	**180.725**
		25	25.00	34.30	232.500	
		30	22.20	34.30	95.460	
		35	20.80	34.30	14.560	
Adult		20	6.40	82.43	399.552	**537.179**
		25	10.40	82.43	597.272	
		30	12.20	82.43	639.646	
		35	10.80	82.43	512.244	
	Nymph to adult					**717.904**

longevity was reduced from 28 d at 20°C to 19-21 d at 25-30°C. At 27°C, the net reproductive rate (R_o) was estimated at 165female/female, the intrinsic rate of population increase (r_m) was 0.119 (@and/@and/d), the generation time (T_c) was 43 d, and the doubling time (DT) was 5.8 d.

Effect of temperature on the life history of the mealybug *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Pseudococcidae) was investigated in the laboratory. *P. marginatus* was able to develop and complete its life cycle at 18, 20, 25, and 30 ± 1°C. At 15, 34, and 35°C, the eggs hatched after 27.5, 5.9, and 5.5 d of incubation, respectively, but further development of the I instar nymphs was arrested. Adult longevity, and preoviposition and oviposition periods increased with decreasing temperature up to 25°C. The proportion of females was H"42 per cent at 25°C and was between 70 and 80 per cent at 18, 20, and 30°C. Adult males and females required 303.0 and 294.1^{0}D (DD), respectively, to complete their development. The estimated minimum temperature thresholds for the adult males and females were 14.5 and 13.9°C, respectively. For adult males, the estimated optimum and maximum temperature thresholds were 28.7 and 31.9°C; and for adult females, they were 28.4 and 32.1°C, respectively. The ability of *Paracoccus marginatus* to develop, survive, and reproduce successfully between 18 and 30°C suggests that it has the capability to develop and establish in areas within this temperature range (Amarasekare *et al*, 2008).

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Participatory evaluation of ergonomically designed cotton picking bags

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ABSTRACT : Ergonomically designed cotton picking bags from Marathwada Agriculture University, Parbhani and CCS, Haryana Agriculture University) were evaluated in participatory mode with Bt hybrid cotton under rainfed condition during 2008-2011 in Nagpur for its suitability in drudgery reduction along with local method. Family resource management division, CCS, HAU, Hissar ergonomically designed cotton picking bag was having 50 per cent higher carrying capacity and ease in tying proved significantly superior over Home Science department, MAU, Parbhani designed picking bag as it facilitated longer picking time with less interruptions. HAU bag exerted 37 per cent less load on heart beats, 18 per cent lower energy expenditure KJ/kg cotton with a break even of 17 days. Cotton picking bags can be locally stitched, if used 45-60 days in a season with proper hygiene offers body protection and improves picking efficiency. HAU bag requires 25 per cent and 15 per cent extra cloth and costs over MAU bag although, without any protection of hands. HAU cotton picking bag is meeting the objective of ergonomic requirement. Cotton picking bags or age groups did not differ significantly on output due to light to moderate nature of work load with frequent breaks.

Key words : Cotton picking bags, drudgery reduction, ergonomic designs, farm women, onfarm evaluation, women centered technology

Introduced *Bt* hybrid cotton during 2004-2011 became very popular and replaced the area of existing *Gossipum hirsutum* hybrids and *G. arboreum* cotton. Large scale *Bt* hybrid cotton cultivation brought changes in picking of cotton by limited available picking women and rise in cost of seed cotton picking ₹ 2-5/kg during rise in MSP of cotton. Recent rise and fall in selling price of cotton in 2010 and 2011, respectively reduced margins for cotton producers. Labour shortages for weeding and picking have been experienced in intensively cultivated Andhra Pradesh and Tamilnadu states. Hand picking operation requires 450-500 women-h/ha which costs US $.113/t and $ 79-248/ha (Chaudhary, 2011). Delayed picking can spoil the fibre quality and grade of cotton due to unseasonal rains and hail storms. Cotton picking manually involves drudgery due to posture, load carrying and abrasion of fingers. An aid to reduce drudgery, efficient collection and field transportation in manual cotton picking would improve the picking efficiency. Cotton picking bags were ergonomically designed, tested and popularized to improve cotton picking efficiency and reduce trash content. The present onfarm adoptive research was concentrated on evaluation of ergonomically designed cotton picking bags in participatory mode by cotton farm women for reducing the drudgery and adoptability.

MATERIALS AND METHODS

A onfarm research project was conducted during 2008-2011 for evaluation of cotton picking bags designed and tested by Marathwada Agriculture University, (MAU), Parbhani, CCS Haryana Agriculture University, Hisar suitable to different age groups and data analyzed in factorial design. Breakeven for cotton picking bag was calculated from extra earnings received due to improved cotton picking efficiency.

Selection and training of subjects : Eighty one farm women in the age range of 18 to 52 years with normal health/ blood pressure and body temperature were selected from Hingna, Kalmeshwar and Nagpur *tahasils* of Nagpur. Care was taken to avoid any subjects with any major illness or cardiovascular problems. Knowledge, skills for using these picking bags were imparted and allowed them to use for dummy picking.

Classification of subjects : Height and body weight of cotton picking women were measured for calculating body mass index (BMI), scores were interpreted as per Garrow (1987). Heart beats/ min were measured before and after cotton picking operation in cotton fields, energy expenditure (kJ/min), output of seed cotton and area covered, frequency of emptying, time required for filling and emptying of the bags were counted.

Stitching of bags: Cotton picking bags alongwith technical literature were procured from original source (MAU, Parbhani, CCS, HAU, Hisar) and got them stitched with locally available tailor.

Testing of cotton picking bags: Cotton picking efficiency, energy expenditure, carrying capacity, ease, comfort, safety, loading and unloading etc were documented for comparison among bags. Output of *Bt* hybrid cotton picked was measured/unit area and time using all two picking bags and local picking aid called *Fadka* or a piece of old cotton /synthetic cloth usually tied around the waist of farm women to temporarily store and transport cotton picked in field besides covering head with a cloth and old male full sleeves shirt for protection from dust, sun and abrasion.

Computations: Out put of seed cotton/h, delta heart beat, seed cotton picked/h, Energy required/kg seed cotton, picking efficiency as time spent on actual picking to that of emptying and field walking was calculated from this during *Bt* hybrid cotton picking.

Masculo skeletal problems: Incidences of musculo-skeletal problems during the activity were identified with the help of body map, which indicates different body parts *viz;* upper body parts (eye, neck, shoulder joint, upper arm, elbows, wrist/hands) and lower body parts (lower arm, low back, upper leg/ thigh, knees, calf muscles, ankles, feet). The perceived discomfort *i.e.* rating of perceived exertion (RPE) was recorded in terms of pain felt on a 5 point scale developed by Varghese *et al.,* (1994) to record the intensity of the pain in the various parts of the body *viz.*, 5, 4, 3, 2, 1 for the intensity of the pain as very severe, severe, moderate, mild and very mild respectively.

RESULTS AND DISCUSSION

Ergonomic evaluation of cotton picking bags : Family resource and management division, CCS, HAU, Hissar ergonomically designed back loaded cotton picking bag was having 50 per cent higher carrying capacity ease in tying, facilitated longer picking time and less interruptions (Table 2) proved significantly superior over Home Science department, MAU, Parbhani designed front loaded pouch type of cotton picking bag. HAU bag exerted 37 per cent less load on heart beats, 18 per cent lower energy expenditure KJ/kg cotton (Table 1) with a breakeven of 17 days (Fig.1) due to ease in field movement compared to front loaded MAU bag which created hindrance in walking. Although the differences earnings among cotton picking bags were not statistically significant but their ergonomical value is in improving the cotton picking efficiency. These results were in agreement with those observed the suitability of cotton picking bags under Haryana conditions (Gandhi, *et al.*, 2008). HAU, designed cotton bag requires 25 and 15 per cent extra cloth and costs over MAU bag although, without any protection of hands (Fig.1). MAU, designed cotton picking bag only offers protection for arms and legs from sun and physical abrasion of cotton bracts and special extra linen is needed in rest. The conventional cloth system exerted more load on left knee due to forward motion with front load of cotton. However, the cotton cloth selection made in the improved picking bags also created less suffocation compared to synthetic cloth used in the local method needs attention of researchers for further comfort.

Onfarm evaluation of cotton picking bags : Average heart rate at rest beats min^{-1} and after work was non significantly influenced by both picking bags and age groups due to lighter nature of physiological work load both in improved picking bags and younger and middle age group (18-35year) of farm women compared to traditional picking tool *Fadka* in higher age group(36-52 years) as moderate nature of work as described by Garrow (1987). These observations were confirmed from energy

Table 1. Onfarm evaluation of cotton picking bags in Nagpur district

Picking bags	Average rest HRb/ min	Average working HRb/ min	ΔAWHR over rest/b min	Output kg/h	Output area/h	BMI	Energy expen-diture kJ min	Δ AWHR over rest b min/kg	Δ AWHR rest b/min	Earning day	Pickers/ ha	Energy expend-iture/kg cotton picking	Physiological work load	
													Energy expendi-ture kJ / min	HR b/ min
HAU	83.9	105.0	21.1	5.3	75.1	16.4	8.0	5.3	6.4	127.3	33.2	642.2	M*	L*
MAU	82.9	100.5	17.6	4.9	85.1	17.7	7.3	4.7	10.1	120.6	26.2	780.4	L	L
TT	81.6	105.6	24.0	4.8	61.8	17.9	8.1	6.8	3.0	134.4	34.0	481.7	L	M
SE	2.5	3.9	3.4	0.5	15.5	0.6	0.6	1.0	4.3	17.0	6.9	161.5		
p=0.05														
Age group of women pickers involed in on farm evaluation														
18-25	84.6	101.6	16.9	5.0	72.6	17.0	7.4	4.3	9.6	122.7	30.4	679.0	M	L
26-35	80.7	103.9	23.2	4.7	69.7	17.5	7.8	6.6	4.3	126.6	35.0	579.7	M	L
36-52	83.1	105.7	22.6	5.4	79.8	17.5	8.1	6.0	5.6	132.9	28.0	645.7	M	M
SE	2.1	3.0		0.4	10.7	1.0	0.5	0.0	2.7	11.8	3.7	100.5		
p=0.05			4.5					1.5						
Interaction														
SE	11.5	16.8	12.4	2.3	56.0	5.4	2.7	4.4	14.7	65.0	20.5	554.0		

*L=light, M=Moderate

Table 2. Ergonomic evaluation of cotton picking bags in Nagpur district.

Parameters of evaluation	HAU bag	MAU bag	Traditional tool	p=0.05
Carrying capacity (kg)	6	3.75	4	0.92
Ventilation/discomfort	100	100	95	2.47
Safety/ Comfortability				
Protection for arms and legs	0	42	0	26.04
Suitability and liking				
Frequent emptying	100	68.75	67.5	10.42
Tying ease/difficult	100	100	100	0.00
Cost of bag	137.5	38.75	175	39.67
Body discomfort				
Mid back		33.75	32.5	3.11
Lower back		32.5	33.75	3.11
Left knee		27.5	32.5	4.47
Right knee		22.5	22.5	2.23
Left foot		22.5	22.5	2.23
Right foot		22.5	22.5	2.24
Shoulder left	10			0.00
Shoulder right	10			0.00

expenditure k J/h/kg picked cotton. However, the delta average working heart rate beats/min during picking was significantly lower in relatively younger age group of 18-25 years compared to their senior counter parts 26-35 and 36-52 years due to their anxiety reserved energy can be spent for ease of work. *Bt* hybrid cotton picked area, delta heart beats m-^{2} and quantity hour^{-1} were non significantly influenced by both picking bags and age groups due to the light to moderate nature of work load with frequent breaks in work for emptying the picked cotton from bags as discussed earlier.

Either cotton picking bags or engaging young and middle age groups only to give a higher physiological efficiency in meeting the volume of cotton picking. Selective women power is not possible due to their limited availability of women power for disposal of cotton picking work. Synchronous nature of *Bt* hybrid cotton and timely picking against abnormal weather in a very narrow window of 45-60 days and in general the poor nutritional and energy status of farm women , necessitates to adopt ergonomically efficient picking bags as alternative to make picking under contractual system more ease. The

Fig. 1. Economics of cotton picking bags adopatbility

earning day^{-1} also not significantly influenced by picking bags or age groups may be due to short term job they did for one hour and a break to empty the bag due to lighter nature of work load in a cohesive team manner despite they were on competitive contract by payment basis on quantity of seed cotton picked. The breakeven economics for cotton picking bag was 17 days only compared to picking period of 60 days in every season. It is more vice to make cotton picking bags as apron for farm women themselves which protects and saves energy from the improved efficiency the cost can be realized. HAU cotton picking bag is only meeting the objective of ergonomic requirement.

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Acceptability of cotton picking bag among farm women

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ABSTRACT : Women are engaged in various agricultural operations like presowing, weeding, picking and post picking. All these tasks are time consuming and full of drudgery over the years though there is a paradigm shift towards women empowerment that is not enough. Access to affordable technology reduces drudgery, save time and increases work efficiency of women. Adoption of such technologies radically changes their life. Cotton picking is laborious work. Efforts have been made to develop women friendly cotton picking bag which would reduce the drudgery and increase their efficiency. The present study was carried out in pre dominantly cotton growing areas namely, Sirsa and Fatehabad districts of Haryana. Four villages, namely Nezadela and Bajekan from Sirsa and Bighar and Badopal from Fatehabad district were selected. Out of these four villages, 20 farm women from each village, totaling 80 respondents were selected for intervention programme. Perceived feasibility on 5 attributes was found 82.61per cent. Physical and cultural compatibility attribute was ranked highest with AFI 92.66 per cent. It was followed by relative advantage 89.58 per cent, triability 88.91per cent. However, simplicity complexity was found 61.80 per cent comparatively low index because of cognitive complexity score. Impact of intervention programme was found 43.65 per cent. Grey cotton fabric of 54 inch width was perceived most appropriate for stitching, because of ease in measurements without wastage. Respondents got medium extent of skill acquisition regarding stitching of cotton picking bag.

Key words: Affordable technology, drudgery, perceived feasibility intervention programme

Agriculture is the backbone of Indian economy contributing largest share to the national income. Women are involved in most of farming, animal husbandry and home related activities. The women do the extremely tedious, time and labour intensive works like sowing, weeding and interculture, picking and post harvest operations like shelling, cleaning, grading and processing. All these jobs involve considerable amount of drudgery, because these are done manually, resulting in drudgery and fatigue. Drudgery which is generally conceived as physical and mental strain, fatigue, monotony and hardship experienced by a human being.

Cotton picking is labourious work. On an average, a woman spend six h daily in collecting 20-24 kg of cotton using '*Jholi*' which is a traditional way of making 'conventional bag' out of their own garments and clothing including (*Chunni, Lugdi* and *Chadder*) which is tied in the form of a bag on their shoulders and back. While studying the drudgery aspects like strain and pain experienced during cotton picking hinder their work efficiency. Keeping in mind, all drudgery parameters, cotton picking bag was designed ergonomically to enhance the efficiency of user and reduce drudgery. Cotton picking bag is made of grey cotton fabric or markin cloth and designed as per anthropometric measurements of women. Shaped pockets are provided at the front and below waist level to make the bag comfortable in use. Cushion straps on shoulders make it comfortable to carry cotton weight.

Keeping this in view the present study was undertaken with the objectives, to study the perceived feasibility of cotton picking bag and to assess the impact of intervention programme in terms of knowledge gain, attitudinal change and skill acquisition.

MATERIALS AND METHODS

The present study was conducted in pre dominantly cotton growing areas of Sirsa and Fatehabad districts of Haryana during 2011 and 2012. Out of these two districts, four villages were selected randomly for this purpose namely, Nezadela and Bajekan from Sirsa, Bighar and Badopal from Fatehabad district. Out of these four villages, 20 farm women from each village were selected purposively, who have maximum involvement in cotton picking. Thus, total 80 farm women were drawn as sample of present study. A well blend intervention programme comprised of motivation lecturer, demonstrations, literature, live specimen, posters and home and farm visits was provided to women farmers. After intervention programme a well designed paper pattern of cotton picking bags specially designed for this purpose was provided to the respondents. Stitched cotton picking bag were provided to all the participants for collection of cotton balls. Perceived adoption feasibility was assessed on 4 attributes of innovations, *i.e.* relative advantage, physical and cultural compatibility, simplicity complexity, practicability and triability. Skill acquisition was calculated after intervention programme for preparation of cotton picking bag. Impact was assessed in terms of knowledge gain, attitudinal change and skills acquisition of the respondents. Perceived acceptability was worked out in terms of minimizing health hazards and increasing work efficiency.

RESULTS AND DISCUSSION

Adoption perceived feasibility was assessed on 4 attributes of a new innovation. The data in Table 1 depicted, overall adoption feasibility index of cotton picking bag was found 82.61 per cent which speaks of very high adoption of technology among farm women. Maximum AFI 92.66 per cent was observed on 'compatibility' that is 'physical' as well as 'cultural' compatibility. However, highest rank was assigned to sub attribute of 'situational' and 'social' compatibility followed by cultural compatibility mean score 2.75 and physical compatibility mean score 2.63. This trend seems to be logistic as the farm women found cotton picking bag as 'cultural and situational compatible' at village level.

Regarding relative advantage AFI was found 89.51 per cent. Highest rank was assigned

Table 1. Perceived adoption feasibility of cotton picking bag **Respondents=80**

Attribute	Response category			WMS	Mean score	Rank
	Agree (3)	Undecided (2)	Disagree (1)			
1. Relative advantage						
Low initial cost	50(150)	12(24)	18(18)	192	2.40	V
Monetary benefit	62(186)	4(8)	12(12)	206	2.57	IV
Consistency of use	75(225)	5(10)	0(0)	235	2.93	I
Time saving	65(195)	10(20)	5(5)	220	2.75	III
Multiple use potential	72(216)	8(16)	0(0)	232	2.90	II
Total				1075	**AFI=89.58 (%)**	
2. Compatibility						
Cultural compatibility	65(195)	10(20)	5(5)	220	2.75	II
Physical compatibility	60(180)	10(20)	10(10)	210	2.63	III
Situational compatibility	68(204)	10(20)	2(2)	226	2.82	I
Social compatibility	72(216)	2(4)	6(6)	226	2.82	I
Relational compatibility	60(180)	0(0)	20(20)	200	2.50	IV
Total				1112	**AFI =92.66 (%)**	
3. Simplicity complexity						
Cognitive simplicity	25(75)	10(20)	45(45)	140	1.75	IV
Application simplicity	22(66)	28(56)	30(30)	152	1.90	V
Adoption simplicity	48(144)	20(40)	12(12)	196	2.45	III
Resource simplicity	52(156)	18(36)	10(10)	202	2.52	I
Reversibility	55(165)	10(20)	15(15)	200	2.5	II
Total				890	**AFI = 61.80 (%)**	
4. Practicability						
Communicability	42(126)	8(16)	30(30)	172	2.15	IV
Visibility of results	80(240)	0(0)	0(0)	240	3.0	I
Demonstrabity	75(225)	5(10)	0(0)	235	2.93	II
Triability	60(180)	10(20)	10(10)	210	2.62	III
Provision of modification	60(180)	10(20)	10(10)	210	2.62	III
Total				1067	**AFI= 88.91 (%)**	
Grand Total					**Overall AFI = 82.61 (%)**	

WMS – Weighted mean score; AFI – Adoption feasibility index; Figure in parenthesis shows corresponding frequency to the 'consistency of use' sub attribute having mean score 2.93 which was followed by 'multiple use potential' mean score 2.90, respectively. This seems to be fact because women reported that this cotton picking bag can be used for vegetable and fruit picking. However, comparatively low mean score was assigned to the sub attribute of 'low initial cost' having mean score 2.40 and lowest rank (rank V). This might be due to the fact that grey cotton fabric (*Malacia*) and raw cotton fabric (*Markin*) cost more as compared to unused synthetic fabric used for traditional '*Jholis*'.

Adoption feasibility index for practicability attribute was found 88.91 per cent. Highest rank was assigned to the sub attribute of 'visibility of result' having mean score 3 followed by demonstrability mean score 2.93. It is interesting to note that all the respondents were agreed that results are visible after intervention programme. Comparatively low mean score (2.15) was assigned to sub attribute 'communicability'. This might be due to the fact that farm women needed more exposures and technical know how to communicate further.

As regards simplicity complexity AFI was found 61.80 per cent, comparatively low. Hence, 'cognitive simplicity' scored was low at 1.56 mean score and application simplicity (2.45). This trend showed that farm women required more exposures, action trainings and interventions regarding preparation of cotton picking bag which may be effective by using aid *i.e.* paper pattern according to anthropometric measurements of individual variables. However, resource simplicity got Ist rank (m.s 2.51) and reversibility (2.5), IInd rank. This trend shows that material required for cotton picking bag is easily available. The study finds conformity with Yadav *et al.,* (2012).

Fig. 2 showed that skill acquisition of the respondents was assessed by stitching of cotton picking bag without using paper pattern and with the help of paper pattern. It is evident from the Table that after intervention programme about half of the respondents (52.5%) could succeeded in stitching of cotton picking bag upto a medium extent. However, only 2.5 per cent of the respondents were adjudged highly skilled in stitching of cot bag according to individual anthropometric measurements. Further, it is interesting to note that majority of the respondents 92.5 per cent were found highly skilled in stitching cotton picking bag according to anthropometric measurements. This seems to be true as the farm women found difficult to

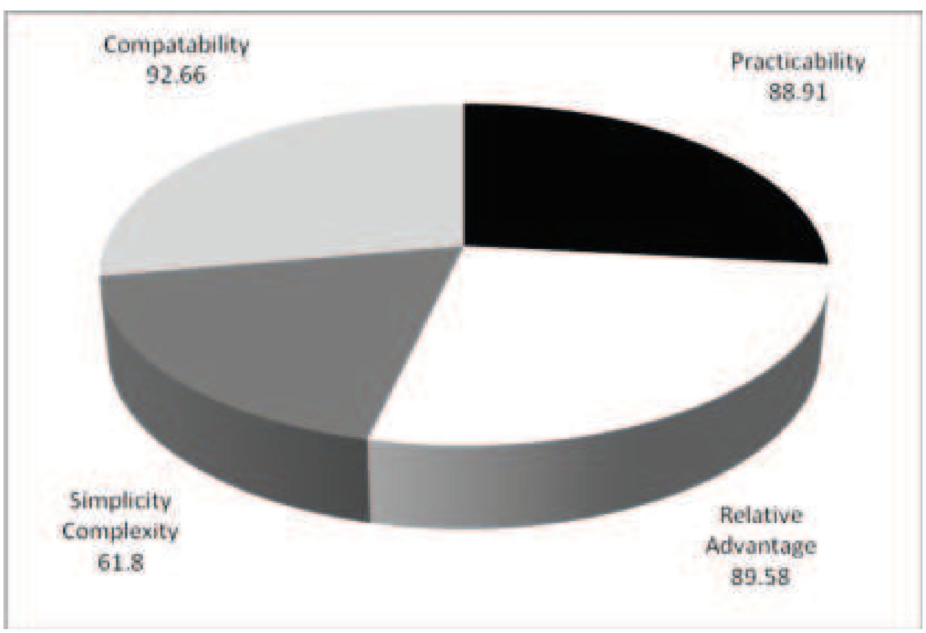

Fig. 1. Adoption Feasibility Index of cotton picking bag

cut and stitch cotton picking bag according to anthropometric measurements on different width fabrics. Whereas paper pattern was found a useful technique to cut and stitch as per anthropometric requirements. This study is in consonance with the findings of Gandhi *et al.,* (2004).

Table 3. Impact of intervention programme on farm women **Respondents=80**

Attitude/Skills	Knowledge		
	High(3)	Medium(2)	Low(1)
Favourable (3) H (3)	955	622	211
Somewhat favourable (2) M (2)	486	212	121
Unfavourable (1) L (1)	522	420	320
Total	**40**	**21**	**19**

Impact Assessment Index was worked out by taking into account three dimensions *viz.,* knowledge acquired, attitudinal change and skill acquired on three point continuum, their respective frequencies were computed and presented in 3x3x3 (Table). The cell entries depict the scores obtained by subtracting pre form post exposure scores on as all three dimensions. The impact assessment index was then computed with the help of formula given below:-

$$IAI = \frac{fi \times Ci}{Nxxxy \times Z} \times 100 = 43.65\ (\%)$$

Where
IAI = Impact Assessment Index
Fi = Frequency in ith cell
Ci = Cell scores of ith cell
N = Total respondents
X = Highest scale value on x dimensions
Y = Highest scale value on y dimensions
Z = higher scale value on z dimensions

The impact assessment of intervention programme was found to be 43.65 per cent. It may be interred that women respondents after intervention programme succeeded in acquiring knowledge, changing their attitude and acquiring skill upto a moderate level. This seems to be logistic because intervention programme imparted on need based technology and it's suitability is to be determined accordingly. However, they needed some more exposure on some of the aspects of technical know-how of stitching of cotton picking bag according to anthropometric measurements. The results are in line withAnonymous, 2009.

Acceptability of cotton picking bag was worked out on health and working efficiency related parameters. It is evident from the data presented in Table 4 that majority of the respondents (90.0%) reported that they feel strain on shoulders after picking of cotton for a long duration of 5 to 6 h. These were followed by pain in hand (83.75%) and pain in back (35.0 %) respectively. It is interesting to note that only a few of the respondents (6.25%) feel stressed on shoulders after picking of cotton for long duration.

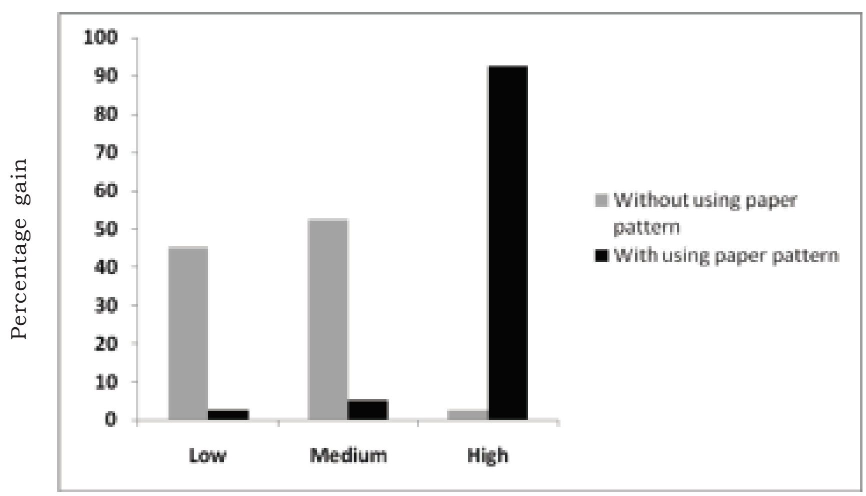

Fig. 2. Skill acquisition of respondents regarding of stitching of cotton picking bag

Table 4. Perceived acceptability of cotton picking bag by farm women **Respondets =80**

Parameter Health related	Conventional bag Frequency	 Percentage	Cotton picking bag Frequency	 Percentage
Strain on shoulder	72	90.00	5	6.25
Pain in hand	67	83.75	12	15.00
Pain in back	28	35.00	12	15.00
Pain in neck	5	6.25	-	-
Pain in wrist	-	-	-	-
Working efficiency related	**-**	**-**	**18**	**22.5**
Time taken for one loading				
Less than ½ to one h	10	12.50	60	75.00
More than one h	70	67.50	2	2.500
Provision of modification as per body measurements	-	-	80	100.0
Multiple use potential	2	2.50	80	100.0

However, 15.0 per cent of them reported hand and back pain also in cotton picking.

Regarding working efficiency related parameters, it is evident from data that majority of the farm women 67.5 per cent take more than one h in picking one loading (one *Jholi*) in conventional bag followed by 12.5 per cent in ½ to 1 h, whereas in cotton picking bag which is designed as per anthropometric measurements 75.0 per cent respondents take upto one h in picking one load followed by 22.5 per cent which take less than one h in picking cotton. This trend showed that cotton picking bag provided during intervention programme helped them to collect more cotton as compared to conventional bag. This seems to be logistic because the bag is designed and stitched ergonomically and per anthropometric measurements. Cushioned straps makes it comfortable on shoulder when reduced stress and hinders pain in hand and back. It's well shaped pocked in front reduces unnecessary body movements subsequently, it takes less time in cotton picking as compared to conventional bag. Further, all the respondents found it multiple use potential because they use in vegetable and fruit picking also so consistency of use increases accordingly. These findings are in consanance with Gandhi *et al.,* 2011.

CONCLUSION

This paper is an attempt to reduce drudgery and increase work efficiency of farm women in cotton picking, which is a tremendous task and performed by majority of farm women. Perceived feasibility of cotton picking bag was found 88.91 per cent which speaks of high percentage farm women found it advantageous, compatible, and triable technology. Impact was assessed after completion of intervention programme which was found 43.65 per cent in terms of skill acquisition, knowledge gain and attitude change. It was found acceptable on health parameters and helpful in enhancing working efficiency in cotton picking.

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Inter gender work load in cotton cultivation among rural families

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ABSTRACT : The paper is an attempt to study the nature and extent of involvement of rural women and men of various socio economic strata in cotton cultivation, animal husbandry and home activities in terms of operations, time spent, responsibility and accountability. Results indicated that the operations *viz.*, pesticide spraying, irrigation, ploughing, sowing, manure and fertilizer application, uprooting of seedlings and marketing were exclusively performed by men. The accountability in such tasks ranged from 2.89 to 3.47 in all socio economic strata. Thus, the accountability was found to be the highest in case of jointly operated operation followed by female dominated operations whereas male dominated operations had the lowest accountability.

Keyword : Cotton cultivation, decision making, inter gender, women farmers, work load

Women play a significant and crucial role in agricultural development and allied fields. The nature and extent of women's involvement in agriculture, no doubt, varies greatly from region to region. Even within a region, their involvement varies widely among different ecological sub zones, farming systems, castes, classes and stages in the family. But regardless of these variations, there is hardly any activity in agricultural production, except ploughing in which women are not actively involved. Traditionally, cotton picking is exclusively female activity and 89 per cent women are engaged in it. They are also extensively involved in other activities such as 30 per cent in hoeing and 22 per cent in weeding. Aside from these activities, women have very little involvement in other aspect of cotton production, while the males play major role in seed preparation (85%) ridge making (87%), sowing on ridges (54%), hoeing (17%), thinning (44%), and pesticide application (98%), fertilizer application (99%) and seed preparation (87%) (Khalida, 2009). One study in rice and cotton producing villages in Pakistan showed that in agricultural activities women spent 39.34 and 50.42 per cent of their time in rice and cotton growing areas, respectively (Quadri and Jahan, 1982; Anonymus, 1997 and Rashdi, 2002). To study the extent of involvement of rural women and men of various socio economic strata in cultivation and to assess the cotton cultivation operations in terms of responsibility and accountability.

MATERIALS AND METHODS

The study was conducted in Haryana and has been divided in to three zones, *i.e.* hot arid, hot semi arid and hot humid zone on the basis of agro climatic conditions. Two districts namely, Hisar and Karnal from two regions *i.e.* hot humid and hot semi arid, respectively of the state were purposively selected. Two villages from each district *i.e.*, Mehmoodpur and Gogripur of Karnal, Shahpur and Patan of Hisar were selected randomly for collection of data. The data were collected with the help of structured interview schedule from 100 farm women and men (their husbands).

Responsibility: It was measured with the help of structured close ended questions. The respondents were asked for the responsibility of husband only, wife only, husband and wife both and any other member of family for agricultural operations.

Accountability: The accountability was measured for each agricultural operation. The scores assigned were ;

Very much accountable	5
More accountable	4
Neither more nor less accountable	3
Less accountable	2
Very less accountable	1

Average accountability score is calculated according to his or her responsibility category in different socio economic strata. This is calculated by the formula. Sum of each respondents score of accountability in responsibility category

Average accountability score = Total number of respondents in each responsibility category

RESULTS AND DISCUSSION

The data reported in Table 1 depicted that in case of cotton cultivation, there are six operations namely ; pesticide application, irrigation, ploughing, sowing, manure and fertilizer application and marketing exclusively performed by men. The remaining six operations weeding by *kasola,* weeding by *khurpi,* carrying load on head, and picking were such observations performed by both men and women. Out of these six operations, carrying load on head is predominantly performed by women (over 80%). The other operations *viz.*, weeding by *kasola* and *khurpi* in cotton (51.1%) crops is predominantly performed by women. Even in case of picking more than 90 per cent was taken up by women. The heavy pre occupation of women in these six operations have resulted in substantially higher labour contribution by them in cultivation of cotton crop. On an average a women devotes 28.42 against 19.83 man days devoted by a men in cultivation of one acre of cotton. They spend more than half of their man days (deployed in cotton cultivation) only in these operations which they carry either with the help of *khurpi and kasola*. Simillarly, cotton picking, weeding, were also the major jobs of womenfolk engaged in agriculture. Studies by Sharma (2003) and Kumar *et al.,* (2012) conducted in different part of India also support the present finding.

Table 1. Farm operation undertaken by men and women in cotton cultivation **Respodents=50**

Operations	Unit: Men	Unit: Women
Male Dominated operations		
Pesticide application	88.3 (100.0)	-
Spade work during field irrigation	94.6 (100.0)	-
Field preparation	166.2 (100.0)	-
Manure and fertilizer application	49.5 (100.0)	-
Uprooting of seedling	-	-
Marketing of produce	44.7 (100.0)	-
Female dominated operations		
Weeding by *kasola*	376.0 (48.8)	393.0 (51.1)
Weeding by *khurpi*	-	-
Carrying load on head	10.0 (13.3)	65.0 (86.6)
Jointly operated operations		
Cotton picking	28.0 (4.2)	632.0 (95.7)
Harvesting	67.0 (16.8)	331.0 (83.1)
Total	**991.3**	**1421.0**
Average	**19.83**	**28.42**

Involvement in various operations-inter sex variation : Involvement of men and women in various operation of cotton cultivation were reported in Table 2 which revealed that the

Table 2. Involvement in various operations inter sex variation

Operations	Socio economic status	Man days: Male (Mean score)	Man days: Female (Mean score)	't' Value
Male dominated operations	High	9.5	0.0	19.81*
	Medium	8.9	0.0	23.23*
	Low	11.1	0.0	22.34*
	Total	**10.2**	**0.0**	**30.49***
Female dominated operations	High	6.5	8.2	-1.66
	Medium	7.7	8.5	-0.75
	Low	8.0	9.7	-2.24*
	Total	**7.7**	**9.1**	**-2.60***
Jointly operated operations	High	0.0	17.6	-23.40*
	Medium	4.1	18.0	-5.52*
	Low	4.2	20.4	-15.65*
	Total	**2.9**	**19.2**	**-16.79***
Overall operations	High	16.0	25.8	-6.78*
	Medium	20.7	26.6	-2.30*
	Low	20.8	30.1	-6.57*
	Total	**19.8**	**28.4**	**-7.36***

* Significant at 0.05 level of probability

overall involvement of female (in terms of average man days) was quite high than male in high, medium and low socio economic strata as well as in case of total respondents. There was significant difference between men and women's work load in cotton cultivation. It may, therefore, be inferred that women's work load in cotton cultivation was higher than men. In male dominated operations women's involvement was negligible in different socio-economic strata as well as among pooled sample.

The mean score of women's involvement was higher than men in high, medium, low and pooled data in female dominated operations (weeding by *kasola*, carrying load on head). In jointly operated operations (cotton picking), the mean score of women's work load was more substantial than men in all socio economic strata categories and in pooled data. The average work load of low socio economic strata women was higher than those of the high and medium socio economic strata and among pooled data. It may, therefore, be concluded that low socio-economic stratum women performed extensive work in crop

Table 3. Responsibility and accountability of male and female for various farm operations

Sr. Operations		Socio economic status					
		Responsibility			Accountability		
		High	Medium	Low	High	Medium	Low
Male dominated operations							
Field preparation	Joint	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0
	Husband	18.0 (100.0)	29.0 (100.0)	53.0 (100.0)	3.0	2.6	2.6
	Wife	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0
Sowing	Joint	00.0 (00.0)	2.00 (6.90)	3.0 (5.74)	00.0	3.0	3.0
	Husband	18.0 (100.0)	27.00 (93.1)	50.0 (94.31)	3.1	2.5	2.6
	Wife	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0
Manure and fertilizer application	Joint	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0
	Husband	18.0 (100.0)	29.0 (100.0)	53.0 (100.0)	3.0	2.7	2.5
	Wife	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0
Plant protection measures	Joint	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0
	Husband	18.0 (100.0)	29.0 (100.0)	53.0 (100.0)	2.8	3.1	3.0
	Wife	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0
Irrigation	Joint	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0
	Husband	18.0 (100.0)	29.0 (100.0)	53.0 (100.0)	3.1	3.27	3.0
	Wife	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0
Marketing	Joint	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0
	Husband	18.0 (100.0)	29.0 (100.0)	53.0 (100.0)	3.2	3.1	2.6
	Wife	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0
Female dominated operations							
Weeding	Joint	01.0 (5.6)	7.0 (24.11)	11.0 20.7)	2.8	2.7	2.6
	Husband	6.0 (33.3)	0.0 (0.00)	2.0 (3.78)	3.3	0.0	3.4
	Wife	11.0 (61.1)	22.0 (75.14)	40.0 (75.51)	3.0	3.2	3.4
Thinning	Joint	2.0 (11.1)	7.0 (24.1)	10.0 (18.8)	2.7	2.8	2.4
	Husband	5.0 (27.7)	4.0 (13.7)	7.0 (13.2)	3.4	3.1	2.4
	Wife	11.0 (61.1)	18.0(62.0)	36.0 (67.9)	3.0	2.8	2.9
Gap filling	Joint	2.0 (11.1)	7.0 (24.1)	10.0 (18.8)	2.8	2.8	2.5
	Husband	5.0 (27.7)	4.0 (13.7)	7.0 (13.2)	3.6	3.2	2.8
	Wife	11.0 (61.1)	18.0 (62.0)	36.0 (67.9)	3.0	2.8	2.6
Sun drying	Joint	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0
	Husband	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0
	Wife	18.0 (100.0)	29.0 (100.0)	53.0 (100.0)	3.07	3.0	3.1
Taking bundles to home	Joint	5.0 (27.7)	10.0 (34.4)	12.0 (22.6)	2.8	2.9	2.82.8
	Husband	2.0 (11.1)	00.0 (00.0)	00.0 (00.0)	2.6	0.0	0.00.0
	Wife	11.0 (61.1)	19.0(65.5)	41.0 (77.3)	3.0	3.6	3.0
Jointly operated operations							
Cotton picking	Joint	12.0 (66.6)	29.0(100.0)	53.0 (100.0)	3.1	3.1	3.0
	Husband	6.0 (33.3)	00.0 (00.0)	00.0 (00.0)	3.4	0.0	0.0
	Wife	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0
Harvesting	Joint	12.0 (66.6)	29.0(100.0)	53.0 (100.0)	3.0	2.9	2.8
	Husband	6.0 (33.3)	00.0 (00.0)	00.0 (00.0)	3.4	0.0	00.0
	Wife	00.0 (00.0)	00.0 (00.0)	00.0 (00.0)	00.0	00.0	00.0

cultivation than high and medium socio economic strata women. This may be due to economic compulsions of earning their livelihood through working in field as agricultural labourer. They seldom hesitate to work even on low wages.

The data regarding responsibility and accountability were reported in Table 3. The responsibility has been worked out in percentage and accountability has been worked out. The responsibility and accountability as reported in Table 3, reveal that there are male dominated operations *viz*., field preparation, sowing, manure and fertilizer application, plant protection, irrigation, in all socio economic strata. The accountability in field preparation for high socio economic strata was 3.0 which were followed by 2.6 and 2.6, respectively of the respondents of medium and low socio economic strata. The accountability of the respondents in male dominated operations ranged from 2.8 to 3.2 in high socio economic strata, 2.5 to 3.2 in medium socio economic strata and 2.5 to 3.0 in case of low socio economic stratum. The female dominated operations *viz.,* weeding,, thinning, gap filling, sun drying, keeping part of produce for consumption and taking the bundles of harvested crops to home were the responsibility of wife (over 60%) in all socio economic strata. The accountability of female respondents in female dominated operations ranged from 2.0-4.0 in the high socio economic status, 2.6 to 3.6 in medium socio economic status and 2.4 to 3.5 in case of low socio economic stratum. The jointly performed operations of cotton picking and harvesting were the joint accountability of joint respondents ranged from 2.8 to 3.4 in all socio economic strata. It can however, be concluded that the accountability is more in case of jointly operated operations followed by female and male dominated operations.

CONCLUSION

Results indicated that the operations *viz.,* pesticide application, spade work during irrigation, ploughing, sowing, manure and fertilizer application, thinning and marketing were exclusively performed by men. Even in case of cotton picking more than 90 per cent is taken up by women. The remaining operations, *i.e.*, weeding by *khurpi*, carrying head load, picking and were performed by both of them but man days devoted by women heavily outnumbered the man days devoted by men. Weeding and carrying cotton picking on head were predominantly (to the extent of 90%) performed by women. Even in case of picking, about 70 per cent of the operations were performed by women. The other farm operations like weeding by *kasola,* and *khurpi*, cotton picking (90%), carrying head load, (to the extent of 90%) were performed jointly but predominantly by women. The overall involvement of female (in terms of average man days was quite high than male in high, medium and low socio economic strata). The jointly performed operations had the joint responsibility of husband and wife in all socio economic strata. The accountability of such tasks ranged from 2.89 to 3.47 in all socio economic strata. Thus, the accountability was found to be the highest in case of jointly operated operation followed by female dominated operations whereas male dominated operations had the lowest accountability.

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Adoption and impact assessment of conservation agriculture technologies with special reference to growing of cotton crop with drip irrigation

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ABSTRACT : Study was carried out in Sirsa, Fatehabad and Bhiwani districts of Haryana State. From Sirsa, 4 blocks from Fatehabad 2 blocks and from Bhiwani 5 blocks were selected with the help of officers working at National Horticultural Mission, Sirsa, Fatehabad and Bhiwani. Out of these selected blocks, 30 villages from selected blocks of Sirsa and Fatehabad and 18 villages from the blocks of Bhiwani were drawn for the study who were growing horticultural and cotton crops with drip irrigation. Finally, out of these, 85 farmers from the villages of selected blocks of Bhiwani and 120 farmers from selected blocks of Sirsa and Fatehabad were drawn who were doing cultivation with drip irrigation. So, on the whole, 205 farmers were surveyed from 3 districts with the help of structured interview schedule. Majority of farmers had high level of knowledge (57.07%) and high level of adoption (60.49%) of drip irrigation. Level of adoption of drip irrigation on horticultural and cotton crops was found significantly associated with educational level of farmers, size of landholdings, level of extension contacts, level of mass media exposure and level of socio economic status of farmers. Cummulative impact of drip irrigation on socio economic status of farmers was found high. Regarding constraints, most of cotton grower reported irregular power supply (100%), not getting actual price (72%) and loss of crop due to attack of '*ukhera*' disease (15%) and get adulterated seeds (5%).

Key words : Cotton , impact , knowledge , adoption , constraints

The intensification of agriculture along with increased demand for water from other sectors has put tremendous pressure on the limited water resources in recent years in India. An estimate by the Central Water Commission (CWC) shows that by 2050, the annual requirement of water from all sectors (1447 BCM) would exceed the annual utilizable water from both surface and groundwater sources in India (1122 BCM) (CWC,2005).While the available fresh water supplies for future use have been declining at a faster rate, the requirement of food and other agricultural commodities has been on the rise because of continuous population growth and feed requirement for livestock (Amarasinghe, *et al.,* 2007; Chand, 2007). Since irrigation contributes substantially to the gross production of agricultural commodities, the fast increase in demand for irrigation water puts enormous pressure on policy makers to find ways to improve agricultural production while economizing irrigation water. The conventional method throughout the world for crop cultivation is flood irrigation. It is inefficient in terms of field application efficiency and eventually the overall water use efficiency as it allows heavy losses of water through conveyance and distribution (Shreshtha and Gopalakrishnan, 1993, Rosegrant, *et al.,* 2002). Quite a few supply side efforts have been made to increase the water use efficiency under flood irrigation method in India and elsewhere in the world. However, those efforts and strategies have not made any significant impact on the overall water use efficiency in both canal and groundwater irrigation. Drip irrigation method is a technical measure introduced about two decades back to increase the water use efficiency in Indian agriculture. Under this method, water is delivered directly to the root zone of the crops using pipe network and emitters. This method is entirely different from the conventional method, where water is dispersed to the whole cropland, instead of exclusively to the crop (Narayanamoorthy, 2008).

Though studies on the impact of drip irrigation method on many other crops are available, studies on cotton cultivation under DIM using field level survey data are seldom available especially on the Indian context. Cotton (*Gossypium hirsutum* L.) being the most important commercial crop of India contributes to around

60 per cent of the raw material to the textile industry and provides employment to nearly 60 million people with productivity of 494 kg/ha. . Further impetus to cotton productivity *i.e.,* to the world average of 725 kg/ha is possible through efficient and optimal use of precious on farm inputs *i.e.*, water and nutrient (Sankaranarayanan *et al.,* 2011).

Though cotton is predominantly cultivated as a rain fed crop, about 33 per cent of the cotton area is cultivated by undersurface irrigation method in India. Because of inherent problems associated with the surface irrigation and increased water scarcity, farmers are not able to supply water at the required time interval for cotton, which increases the moisture stress on crops. As a result, farmers are not able to increase the productivity of the crop despite using required yield increasing inputs, The productivity of cotton crop is one of the lowest in the world. The experimental data based studies carried out in different locations show that cotton cultivated under drip irrigation method increases productivity by about 25 per cent and water saving by 60 per cent (INCID, 1994). Realising the importance of drip irrigation method on water saving and productivity, farmers in different parts of India have started adopting it especially in the recent years but the studies are not available to know the impact of growing of cotton with drip irrigation on socio economic status of rural communities especially in Haryana . This study makes an attempt to fill this void using the data collected from farmers cultivating cotton with drip in districts of Haryana state to measure the knowledge and adoption level of cultivation of cotton crop with of drip irrigation technology along with. factors affecting it . Secondly, to assess the impact of culivaton of cotton crop with drip irrigation technology on different aspects of the life of farming community along with constraints involved in the adoption.

MATERIALS AND METHODS

Study was carried out in Sirsa, Fatehabad and Bhiwani districts of Haryana state. From Sirsa 4 blocks *i.e.* Rania, Sirsa, Ellenabad and Bada Gudha and from Fatehabad 2 blocks *i.e.* Fatehabad and Bhattu and from Bhiwani 5 blocks were identified *i.e.* Bhiwani, Siwani, Tosham, Charkhi Dadri and Bawani Khera with the help of officers working at National Horticulture Mission, Sirsa, Fatehabad and Bhiwani. Out of these selected blocks, 30 villages from selected blocks of Sirsa and Fatehabad and 18 villages from the blocks of Bhiwani district were drawn for the study. Finally, out of these, 85 farmers from the villages of selected blocks of Bhiwani and 120 farmers from selected blocks of Sirsa and Fatehabad were drawn who were doing cultivation with drip irrigation. So, on the whole 205 farmers (85 from Bhiwani and 120 from Sirsa and Fatehabad) were surveyed from 3 districts with the help of structured interview schedule. Suitable statistical technique was applied to draw the inferences.

RESULTS AND DISCUSSION

Regarding the area under drip irrigation on horticultural and cotton crops, large majority of farmers (75.12%) were doing cultivation with drip on more than 8 ac. Rest (13.17%) and (11.71%) were using drip upto 4 ac of land and in between 4-8 ac, respectively. Majority of farmers had been using drip on cotton and horticultural crops (66.34%) for more than two years. Rest (23.90%) and (9.76%) were using it for 1-2 years and upto one year, respectively. Large majority of farmers (68.29%) availed the subsidy for drip irrigation upto (50%). On the other hand (28.20%) availed the subsidy upto (90%) and (3.41%) adopted the drip irrigation even without subsidy. Majority of farmers got information about the drip irrigation from officials of National Horticulture Mission (51%) and from relatives (29.76%) etc. Regarding the socio economic status of farmers, majority of farmers had high socio economic status (55.12%) followed by medium (40.49%) and low (4.39%).

Regarding the knowledge about drip irrigation (Fig.1) majority of sampled farmers had high (57.07%) and medium (38.05%) level of knowledge of drip irrigation. Only 4.88 per cent had it. To measure the level of adoption of drip irrigation of the farmers an index was developed by taking into account following para meters (i) number of years of adoption (ii) intensity of drip irrigation (iii) custom service rendered by the owner (iv) adoption practices adopted by farmers. Regarding the level of adoption of drip irrigation

(Table 1) majority of farmers had high level of adoption (56.00%). Rest (35.61%) and (8.3%) had medium and low level of adoption of drip irrigation, respectively.

Table 1. Level of adoption of drip irrigation on horticultural crops and cotton in Sirsa and Bhiwani districts

Level of adoption	Sirsa (N=120)	Bhiwani (N=85)	**Total**
Low	11(9.16)	6(7.06)	**17(8.3)**
Medium	44(36.67)	29(34.12)	**73(35.61)**
High	65(54.17)	50(58.82)	**115(56.09)**
Total	**120(100)**	**85(100)**	**205(100)**

Level of adoption of drip irrigation on horticultural and cotton crops was found affected by multiple socio-economic factors. (Table 2) Age of the farmers was found significantly associated with level of adoption. (Table 2) Majority of farmers belonged to younger age group (62.50%) and middle age group (57.68%) had high level of adoption of drip irrigation. Likewise caste of the respondents and level of adoption of drip irrigation was also found nonsignificantly associated. Adoption level of drip irrigation was relatively high among general castes than other caste groups.

Table 2. Adoption of drip irrigation on horticultural and cotton crops as per socio-economic variables

Table 2.1

Age	Level of adoption			**Total**
	Low	Medium	High	
Young (<25 yrs)	0(0.00)	6(37.50)	10(62.50)	**16(7.80**)
Middle (26-50 yrs)	11(9.91)	36(32.43)	64(57.66)	**111(54.15)**
Old (>50)	6(7.69)	31(39.75)	41(52.56)	**78(38.05)**
Total	**17(8.29)**	**73(35.61)**	**115(56.10)**	**205(100)**

x^2 value = 0.259, highly significant, df = 2

Highly significant association was found between level of adoption of drip irrigation and educational level of farmers. (Table 2.2) Analysis revealed that majority of farmers educated upto graduation and above (69.23%), up to 10+2 (65.2%) and matric (64.71%) had high level of adoption of drip irrigation. On the other hand farmers who were less educated *i.e.* educated up to middle (50.00%) and primary level (45.94%) had medium level of adoption of drip irrigation. So educational level of the farmers influenced the adoption level of drip irrigation of the farmers. On the other hand, level of social participation of the farmers was found non significantly associated with the level of adoption of drip irrigation.

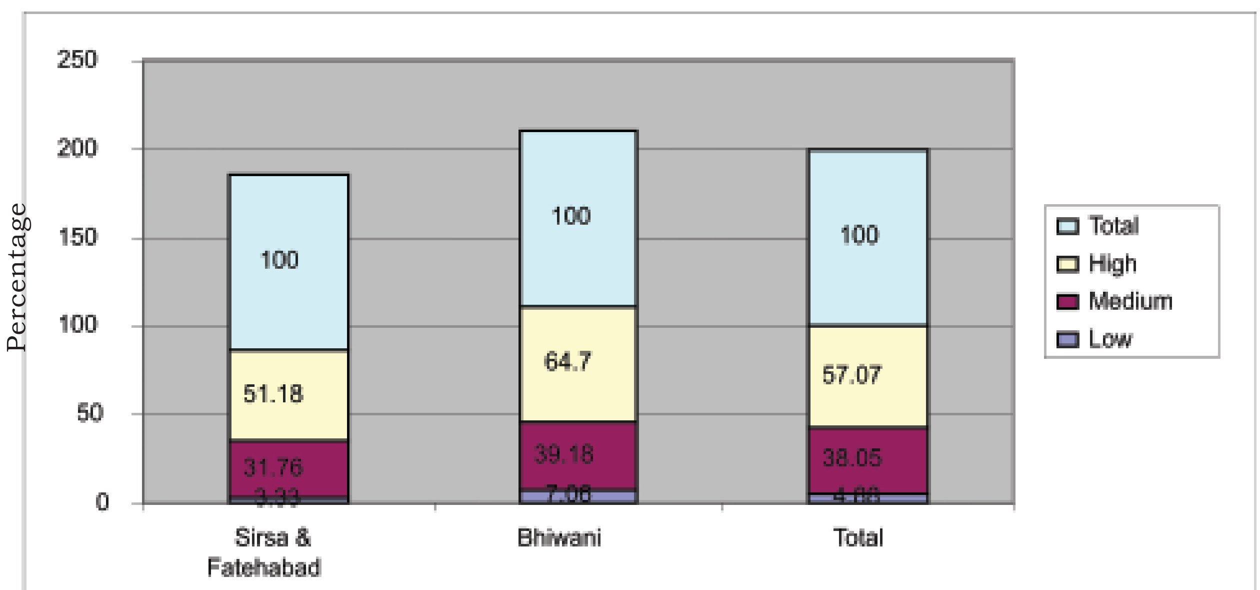

Fig. 1. Level of knowledge of drip irrigation on horticultural and cotton crops in Sirsa, Fatehabad and Bhiwani districts.

Table 2.2

Education	Level of adoption			Total
	Low	Medium	High	
Primary	8(21.63)	17(45.94)	12(32.43)	**37(18.04)**
Middle	3(10.72)	14(50.00)	11(39.28)	**28(13.65)**
Matric	3(44.12)	21(30.89)	44(64.71)	**68(33.17)**
10+2	2(4.35)	14(30.43)	30(65.21)	**46(22.43)**
Graduate and above	1(3.85)	7(26.92)	18(69.23)	**26(15.68)**
Total	**17(8.29)**	**73(35.61)**	**115(56.10)**	**205(100)**

x^2 value = 27.70, highly significant, df = 8

Size of the landholdings was found highly significantly associated with the adoption level of drip irrigation of the farmers. (Table 2.3) Overwhelming majority of very large farmers (81.16%) had high level of adoption of drip irrigation on horticultural and cotton crops. Likewise (52.38%) of large land holders and (49.23%) of medium landholders also had high level of adoption. In contrast, large majority of marginal farmers (75%) had low level of adoption. Majority of small farmers had (52.38%) medium level of adoption of drip irrigation. On the whole, as the size of landholding of the farmers increased, level of adoption of drip irrigation also increased simultaneously. So size of landholding also facilitated the adoption level of drip irrigation of the farmers.

Table 2.3

Size of holding	Level of adoption			Total
	Low	Medium	High	
Marginal farmers	6(75.00)	2(25.00)	0(0.00)	**8(3.90)**
Small farmers	5(23.81)	11(52.38)	5(23.89)	**21(10.24)**
Medium farmers	5(7.69)	28(43.00)	32(49.23)	**65(31.71)**
Large farmers	1(2.38)	19(45.24)	22(52.38)	**42(20.49)**
Very large farmers	00	13(18.84)	56(81.16)	**69(33.66)**
Total	**17(8.29)**	**73(35.61)**	**115(56.10)**	**205(100)**

x^2 value = 82.783, highly significant, df = 8

Level of extension contacts of the farmers also affected the level of adoption of drip irrigation. (Table 2.4) It was found highly significantly associated with level of drip irrigation. Overwhelming majority of farmers who had high level of extension contacts also had high level of adoption of drip irrigation (81.12%). On the other hand farmers who had medium and low level of extension contacts, also had medium level of adoption *i.e.* (56.16%) and (38.10%), respectively. Analysis revealed that as level of extension contacts of the farmers increased there was corresponding increase in level of adoption of drip irrigation.

Table 2.4

Level of extension contacts	Level of adoption			Total
	Low	Medium	High	
Low	13(30.95)	16(38.10)	13(30.95)	**42(20.49)**
Medium	3(4.11)	41(56.16)	29(39.73)	**73(35.61)**
High	1(1.11)	16(17.77)	73(81.12)	**90(43.90)**
Total	**17(8.29)**	**73(35.61)**	**115(56.10)**	**205(100)**

x^2 value = 68.173, highly significant, df = 4

Level of mass media exposure of the farmers also influenced the level of adoption of drip irrigation of the farmers, as both were found highly significantly associated. (Table 2.5) Majority of farmers (79.76%) had relatively high level of adoption of drip irrigation who had high level of mass media exposure and vice-versa. However factors like family type and size of family were found non significantly associated with adoption level of drip irrigation.

Table 2.5.

Mass media exposure	Level of adoption			Total
	Low	Medium	High	
Nil	0	1(100)	0	**1(0.48)**
Low	14(26.41)	23(43.40)	16(30.19)	**53(25.86)**
Medium	2(2.99)	33(49.25)	32(47.76)	**67(32.68)**
High	1(1.19)	16(19.05)	67(79.76)	**84(40.98)**
Total	**17(8.29)**	**73(35.61)**	**115(56.10)**	**205(100)**

x^2 value = 56.617, highly significant, df = 6

Socio economic status of the farmers improved after adopting the drip irrigation on horticultural and cotton crops was found true. (Table 2.6) Analysis clearly revealed that farmers who had high level of adoption of drip irrigation also had high socio economic status and *vice versa*. Significant association was also found between both variables.

Table 2.6:

Socio economic status	Level of adoption Low	Medium	High	**Total**
Low	7(77.78)	1(11.11)	1(11.11)	**9(4.39)**
Medium	8(9.64)	53(63.86)	22(22.90)	**83(40.49)**
High	2(1.77)	19(16.81)	92(81.42)	**113(55.12)**
Total	**17(8.29)**	**73(35.61)**	**115(56.10)**	**205(100)**

x^2 value = 118.81, highly significant, df = 4

On the whole, it can be concluded that factors like general caste status, high level of education, large size of landholdings, high level of extension contacts, mass media exposure and socio-economic status played an important role in the adoption. Therefore, there is a need to improve these factors in rural areas to improve the adoption level of farmers. Low level of adoption was mainly due to low level of education, small size of landholdings, low level of extension contacts, mass-media exposure and socio-economic, status and lack of knowledge.

Impact of drip Irrigation :

Water and electricity saving : The consumption of water in the flood irrigation method is much higher than under drip irrigation method. Therefore, farmers reported that they were not able to supply adequate quantity of water during the time of crop growth mainly due to water shortage and also due to frequent interruptions in electricity supply. So crops had to face either lack of water or excess of water throughout the crop season which has adversely affected the yield of crop. Therefore, all farmers reported that frequent interruptions in electricity supply and water scarcity are the two compelling factors for adopting the drip method of irrigation for horticultural and cotton cultivation. Farmers further reported that before adoption of drip irrigation, it took on an average 8 h to irrigate one ac of land now it has reduced to only one two h/ac. Reduced consumption of water by drip method also reduced the consumption of electricity.

Increase in yield : Drip irrigation technology not only saves water and electricity, but it also increases productivity of crop. Farmers reported that before adopting drip irrigation average yield of the cotton crop was only 10-15 mun/ac but now it has increased to 30-40 mun/ac in Bhiwani district. Similarly in Sirsa district average yield increased from 30-35 to 35-40 mun/ac. Like wise vegetable and fruit growers also reported increase in yield under drip irrigation.

In drip irrigation method, water is supplied only at the root of the crops and not to non crop area, therefore, weed growth is reduced substantially, which reduced the labour requirement for weeding. Moreover, labour and operational costs can also be reduced by simultaneous application of water, fertilizer, insecticide etc through the drip system. Saving of water, electricity, labour work, etc finally reduced the cost of cultivation of crops cultivated under drip irrigation.

Economic impact: Regarding the economic impact of cultivation of horticultural and cotton crops with drip irrigation, all farmers (Table 3) reported saving of water and electricity, increase in yield (97.56%), reduction in cost of cultivation and increase in profit (96.58%) and decrease in labour cost (96.10%). Similarly, benefits like increase in cultivated area (95.61%), decrease in chances of loss of crop due to shortage of water (95.12%), increase in income (94.63%), saving of time (92.19%) were also reported by majority of farmers after adopting drip irrigation.

Due to multiple economic benefits, overwhelming majority of farmers reported many social effects like, (Table 4) improvement in socio economic status (89.27%), increase in household assets (85.36%), increase in social recognition (84.39%), increase in urban and extension contacts (83.41%) and mass media exposure (80.49%). Likewise, farmers also reported improvement in health services availed (73.17%), improvement in dress pattern and educational level (53.17%), change in the attitude towards social issues (22.44%) who adopted drip irrigation on horticultural and cotton crops.

Cummulative Impact : Socio-economic impact of drip irrigation on horticultural and cotton crops was analyzed by cummulating the scores of all positive and negative effects of drip irrigation perceived by the farmers.

Table 3. Economic change experienced by farmers due to adoption of drip irrigation in Sirsa and Bhiwani

	Economic change	Sirsa (N=120)	Bhiwani (N=85)	**Total (N=205)**
1	Increase in water saving and electricity	120(100)	85(100)	**205(100)**
2	Increase in yield	116(96.67)	84(98.92)	**200(97.56)**
3	Reduction on cost of cultivation	114(95.00)	84(98.22)	**198(96.58)**
4	Increase in profit	114(95.00)	84(98.22)	**198(96.58)**
5	Decrease in labour costs	112(93.33)	85(100)	**197(96.10)**
6	Increase in cultivated area	111(92.50)	85(100)	**196(95.61)**
7	Decrease in crop loss	111(92.50)	94(98.22)	**195(95.12)**
8.	Increase in income	111(92.50)	83(97.65)	**194(94.63)**
9.	Saving time	116(96.67)	73(85.88)	**189(92.19)**
10.	Increase in saving	107(89.17)	73(85.88)	**180(87.80)**
11.	Decrease in quality of fertilizer	95(79.17)	80(94.12)	**175(85.36)**
12.	Use of good quality insecticide	94(78.33)	66(77.65)	**160(78.04)**
13.	Use of hybrid variety	91(75.83)	61(71.76)	**152(74.15)**
14	Use of modern agriculture machinery	34(28.33)	49(57.65)	**83(40.49)**
15	Increase in number of animals	34(28.33)	18(21.18)	**52(25.36)**

Factors like educational level of farmers, size of landholdings, level of extension contacts, mass media exposure were found significantly associated with cummulative impact of drip irrigation on horticultural and cotton crops. Farmers who were educated, had large landholdings, high level of extension contacts, mass-media exposure, socio-economic status and relatively large area under drip irrigation experienced high cummulative impact of drip irrigation on their socio-economic status.

Main constraints reported by the farmers while cultivating the cotton crop were (Table 5) irregular power supply (100%), not getting actual price (72%). loss of crop due to attack of 'ukhera' disease (15%) get adulterated seeds (5%).

Table 4. Social change experienced by farmers due to adoption of drip irrigation in Sirsa and Bhiwani

	Social change	Sirsa (N=120)	Bhiwani (N=85)	**Total (N=205)**
1	Change in socio-economic status	103(85.85)	80(94.12)	**183(89.27)**
2.	Increase in house hold assets	116(96.66)	59(69.41)	**175(85.36)**
3.	Increase in social recognition	95(79.17)	78(91.76)	**173(84.39)**
4.	Increase in urban contact/ movement	97(80.83)	74(87.06)	**171(83.41)**
5.	Increase in extension contacts	93(77.50)	78(91.76)	**171(83.41)**
6.	Increase in mass media exposure	89(74.17)	76(89.41)	**165(80.49)**
7.	Improvement in quality of health services availed	93(77.50)	57(67.06)	**150(73.17)**
8.	Change in dress pattern and educational level	51(42.50)	58(68.24)	**109(53.17)**
9.	Change in attitude towards social issues (caste, inter caste marriage, family planning etc)	41(34.17)	5(5.88)	**46(22.44)**

Table 5. Constraints in cotton cultivation with drip irrigation (89)

1.	Irregular power supply. 89 (100%).
2.	Don't get actual price . 58 (72%).
3.	Loss of crop due to attack of diseases39. (15%).
4.	Get cotton seeds adulterated 13 (5%).

Similarly, farmers also reported poor quality of pipes , lack of knowledge about the doses of fertilizer for fertigation non availability of package of practices for the crops grown under drip irrigation problem of clogging .

To improve the adoption level of drip irrigation on cotton crop ;

- Benefits of cultivation of cotton crops under drip irrigation need to be propagated,
- Adoption level of drip irrigation was low among of small and marginal farmers,
- Uninterrupted power supply should be provided,
- Quality of pipes and drippers should also be improved,
- Knowledge should be imparted to farmers about fertigation schedule,

- To develop complete package of practices for various crops grown under drip irrigation.

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Launderings' effect on mechanical parameters of FR treated cotton fabric with combined binders

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ABSTRACT : Flammability of some fibres can be hazardous, therefore they are especially finished to retard flammability. Flame retardant finishes reduce flaming, charring and afterglow of fabrics. To achieve the objective *i.e.* study the launderings' durability of flame finished fabrics on various physical properties, 100 per cent white mercerized cotton fabric, zirconium dioxide as flame retardant (FR) chemical (12% and 15% on the wt. of the fabric) and two binders namely, SLN and PVA were selected on review basis. SLN and PVA were used in combination (2.5% each) with each other. Recipe was made on the weight of the fabric for making suspension of FR finish. To apply flame retardant finish, pad dry cure method on padding mangle was used with 1 dip 1 nip, 2 dip 1 nip and 3 dip 1 nip systems. After application of FR finish, launderings was done 15 times. Mechanical parameters of treated and washed fabrics were assessed. Results indicated that after launderings, fabrics having 15 per cent concentration of FR finish with combined binders gave best results as compared to 12 per cent concentration of FR finish.

Key words: Binders, dip and nip, FR chemical, launderings, padding mangle

Cotton is one of the most versatile fibres which have certain inherent properties making it ideal for different textile and clothing. The extensive use of cotton around the world as a textile fabric owes primarily to the fact that individual cotton fibres have a natural spiral twist, giving it strength and resiliency unmatched by other plant fibres. Hence, certain desirable properties such as dimensional stability, moisture absorption, strength, comfort and softness of cotton has supremacy over other fibers. Some fibres ignite and burn, some smolder and others are non combustible. Different classes of textile fibre respond to direct heat may help in identification of textiles. The use of flame retardant chemicals is still limited in India due to lack of information about suitable FR chemicals to the fabric type, temperature, concentration and binders. Therefore, no much work has been done in India to test mechanical parameters of fabrics treated with FR finish. Keeping in view these factors, the present study was, therefore, undertaken with the objective: to conduct the mechanical parameters of flame finished fabric with combined binders.

Selection of raw material for finish : To conduct the experiment, on the review basis 100 per cent pure white cotton fabric was selected and the material information gathered was as follows:

Fiber content	:	Cotton × Cotton
Colour of the cloth	:	White (mercerized)
Purchased from	:	Local market
GSM	:	220g
Weave	:	Plain
Ends/in (EPI)	:	75
Picks/in (PPI)	:	77
Fabric width	:	44 in

Selection of chemicals for finish : To conduct the experiment, zirconium dioxide was used as flame retardant chemical in two concentrations *i.e.* 12 and 15 per cent separately with two binders namely, silicon liquid nitrile (SLN) and polyvinyl alcohol (PVA) 2.5 per cent each in combination with each other on the basis of weight of fabric.

Applications of FR finish with varying treatments/dips : For 1st application of finish, on the weight of the fabric 12 per cent zirconium dioxide with SLN binder and PVA binder (2.5% each) were mixed in (MLR 1:40) water. Fabric was dipped in that suspension for 5 min and passed out using pad dry cure method in instrument named padding mangle. This is known as 1 dip 1 nip (dipped once in suspension and squeezed once through padding rollers). Curing was done at room temperature and 50 pascal pressure of padding mangle. Fabric was then dried in sun light on grass horizontally. Further application for 2 dip 1 nip (dipped the fabric twice in another suspension and squeezed once) through the padding mangle. Similarly for 3 dip 1 nip accordingly dip thrice and squeezed once. For 2nd application of finish, instead 12 per cent zirconium dioxide, 15 per cent zirconium dioxide was used with same combination of binders and rest of the procedure was same as 1dip 1 nip, 2 dip 1 nip and 3 dip 1 nip system.

Laundering of treated fabrics: Treated fabrics with varying concentration(12 and 15%) of FR finish were laundered following the procedure of AATCC standard (No. 88A-1964T) using 5 per cent neutral detergent solution with material liquor ratio (MLR) 1: 20 at temperature of 25-30^0 C for 5 min. The laundering cycles were carried out 15 times and every 5, 10 and 15 wash cycles, readings were taken of various mechanical parameters.

Measurement of mechanical parameters of treated and washed fabrics

(a) Bending length: Bending length is the length of fabric that will bend under its own weight to a definite extent. It is necessary to find the flexibility of the fabric. It was measured by BS 3356, 1961 test method on "Paramount stiffness tester".

(b) Tensile strength and elongation: Tensile strength is the strength shown by a specimen subjected to tension at distinct from torsion, compression or shear. Elongation is the ratio of the extension of a material to the length of the material prior to stretching. The tensile strength and elongation of fabric was tested on Paramount tensile strength tester "Analogue Model" using IS 4169 test method.

(c) Drape coefficient: Drape coefficient was determined by "drape meter" developed by Bombay Textile Research Association (BTRA) using BS 5058, 1973 test method.

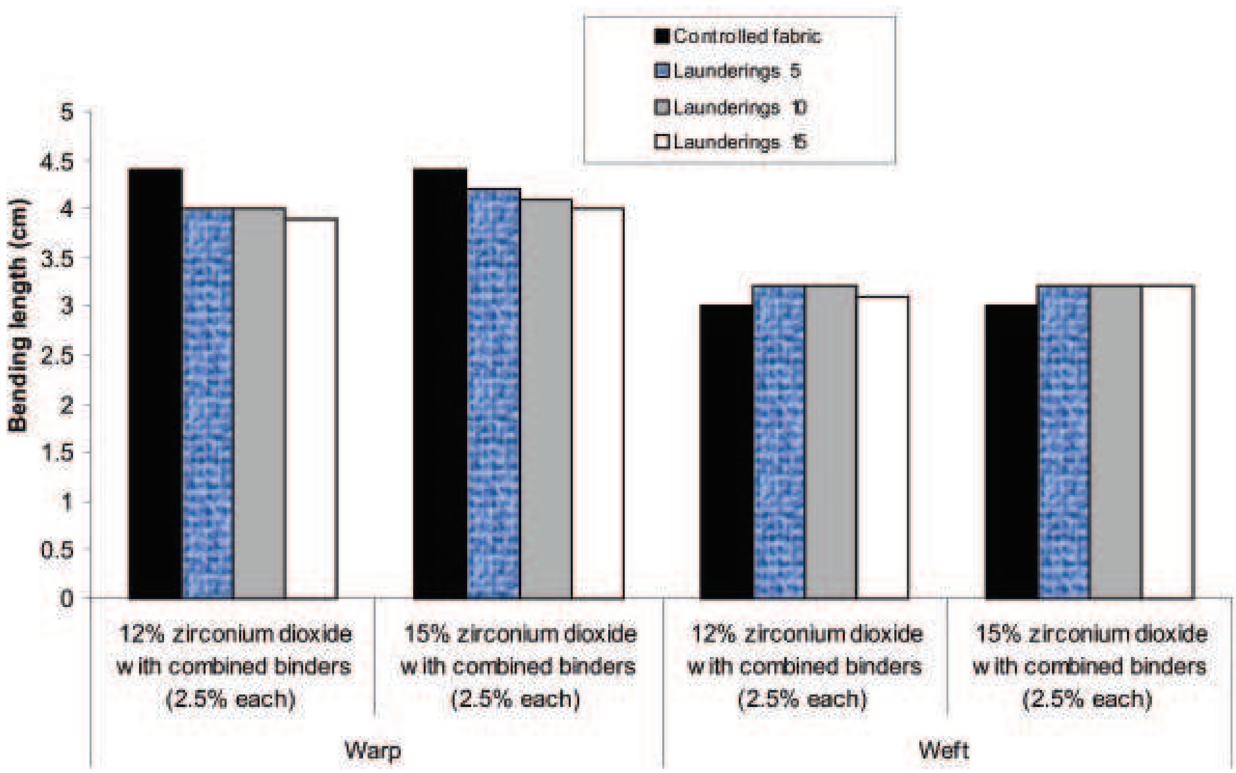

Fig. 1. Bending length of FR finished cotton with combined binders after launderings

Table 1. Mechanical parameters of FR finished cotton with combined binders after launderings

Mechanical parameters		Finish concentrations with combined binders (2.5% each)	Controlled fabric	After 5 washes (After 1 dip 1 nip treatment)*	After 10 washes (After 2 dip 1 nip treatment)*	After 15 washes (After 3 dip 1 nip treatment)*	F-cal	C.D. (p=0.05)
Bending length (cm)	Warp	Zirconium dioxide (12%)	4.3	4.0 (4.0)	4.0 (4.1)	3.9 (4.1)	0.20	0.09
		Zirconium dioxide (15%)		4.2 (4.2)	4.1 (4.7)	4.0 (5.8)		
	Weft	Zirconium dioxide (12%)	2.9	3.2 (3.1)	3.2 (3.1)	3.1 (3.2)	2.56	0.10
		Zirconium dioxide (15%)		3.2 (3.3)	3.2 (3.5)	3.2 (3.6)		
Tensile strength (kg)	Warp	Zirconium dioxide (12%)	60.1	64.0 (73.4)	63.1 (63.1)	60.6 (60.4)	6.36	1.67
		Zirconium dioxide (15%)		59.2 (58.9)	58.2 (58.4)	52.0 (53.6)		
	Weft	Zirconium dioxide (12%)	45.0	29.9 (32.1)	29.8 (24.5)	25.8 (24.4)	14.14	1.86
		Zirconium dioxide (15%)		16.0 (18.0)	14.4 (9.9)	13.5 (8.3)		
Elongation (%)	Warp	Zirconium dioxide (12%)	9.0	7.0 (8.1)	6.9 (8.0)	6.9 (7.8)	0.35	0.22
		Zirconium dioxide (15%)		6.7 (7.9)	6.7 (7.8)	6.7 (7.6)		
	Weft	Zirconium dioxide (12%)	10.0	8.0 (9.0)	8.0 (8.9)	7.9 (9.2)	6.70	0.20
		Zirconium dioxide (15%)		8.1 (9.0)	8.1 (9.0)	7.9 (8.7)		
Drape coefficient (F)		Zirconium dioxide (12%)	0.174	0.177 (0.177)	0.176 (0.179)	0.175 (0.179)	0.70	3.94
		Zirconium dioxide (15%)		0.179 (0.180)	0.179 (0.180)	0.178 (0.181)		

Significant at 5% level
( )* = values of treated FR finished fabric before launderings

Results of treated and washed fabrics presented are as follows:

Data in Table 1 mentioned the mechanical parameters of FR finished cotton with combined binders (2.5 % each) after launderings and it was found that by the application of 15 per cent FR finish with combined binders (2.5% each), bending length observed as 4.2 cm (after 5 launderings) consequently decreased to 4.1 cm (after 10 launderings) and 4.0 cm (after 15 launderings) followed by bending length of treated fabric with 12 per cent finish and combined binders after all the launderings (Fig. 1). Significant difference was calculated 0.09. Ramachandran *et al.,* (2005) did a comparative study on cellulosic fabrics and found that urea with phosphoric acid was found to be the best method in terms of higher flame resistance and better tensile properties and also reduced stiffness character.

The trend in bending length (weft) was observed same as in warp direction. Bending length (weft) increased from 3.2 cm (5 and 10 launderings) to 3.1 cm (15 launderings) with 12 per cent finish and combined binders having CD 0.10 whereas by the application of 15 per cent FR finish with a combination of both (SLN and PVA) binders, bending length (weft) was observed as 3.2 cm after 5, 10 and 15 launderings having critical difference of 0.10. This may be due to absorption of finish by interlacing threads. Mamalis *et al.*, (2001) supports the results as mechanical and surface properties of cotton knitted fabrics after a durable flame retardant finish showed changes as a result of the applied finishing. More specifically, a significant reduction in the bending and shear properties was recorded, which suggested that the flame retardant finishing primarily affects the above characteristics.

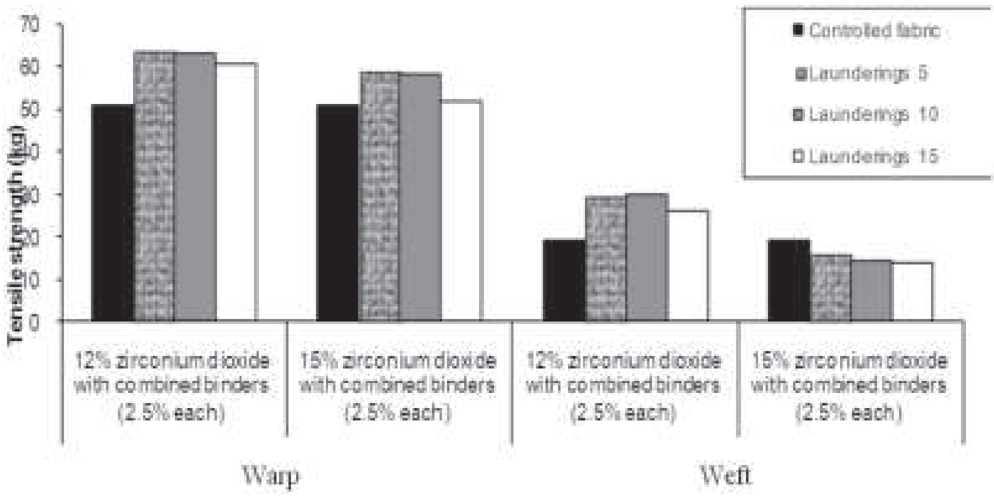

Fig. 2. Tensile strength of FR finished cotton with combined binders after launderings

Data in Table 1 interpreted the results of tensile strength (warp) in Fig. 2 with both finish concentrations. Tensile strength in warp directions increased with 12 per cent finish concentration and combined binders after 5 launderings (64.0 kg) but further decreased as (63.1 kg) and (60.6 kg) after 10 and 15 launderings respectively as compared to tensile strength of controlled fabric (50.8 kg) whereas by the application of 15 per cent finish concentration with the combination of both binders, tensile strength decreased as 59.2, 58.2 and 52.0 kg after 5,10 and 15 launderings, respectively as compared to tensile strength (warp) having significant difference of 1.67.

Trend in tensile strength (weft) was observed in decreased manner after 5 (29.9 kg), 10 (29.8 kg) and 15 launderings (25.8 kg) by the application of 12 per cent finish concentration with combined binders in comparison with tensile strength (weft) of controlled fabric *i.e.* 19.3 kg and it further decreased with 15 per cent finish concentration with both binders as 16.0, 14.4 and 13.5 kg after 5, 10 and 15 launderings, respectively with CD 1.86.

It is evident from the data in Table 1 and Fig. 3 that elongation (warp) of controlled fabric was measured 8.0 per cent. With the application

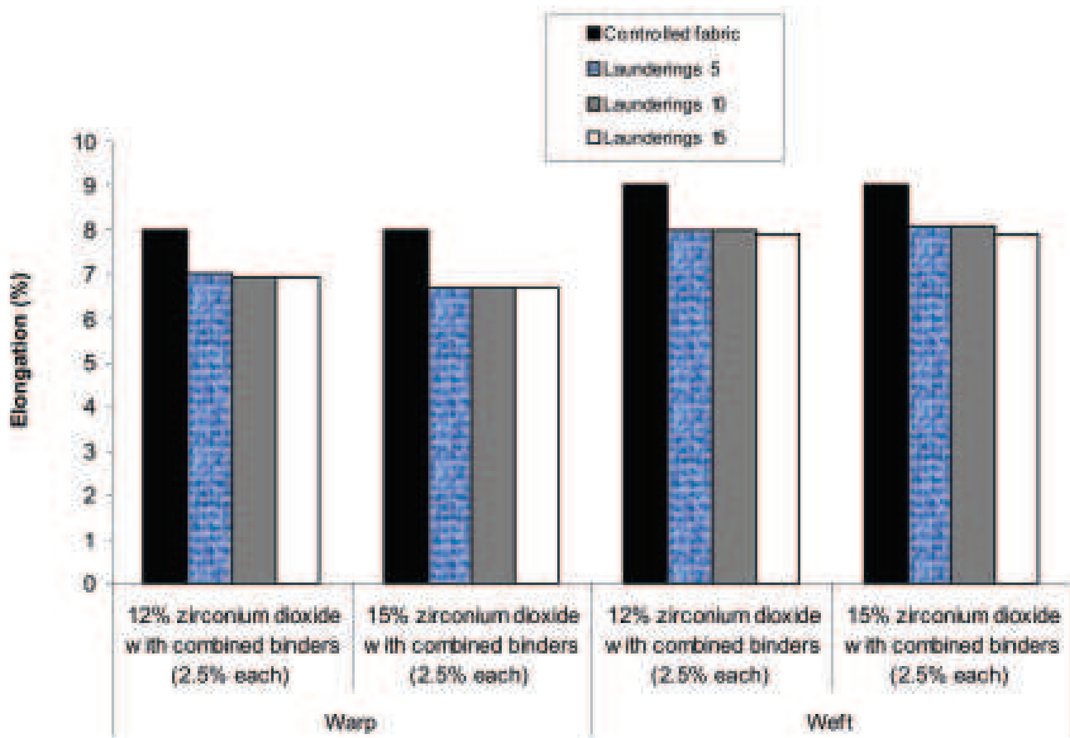

Fig. 3. Elongation of FR finished cotton with combined binders after launderings

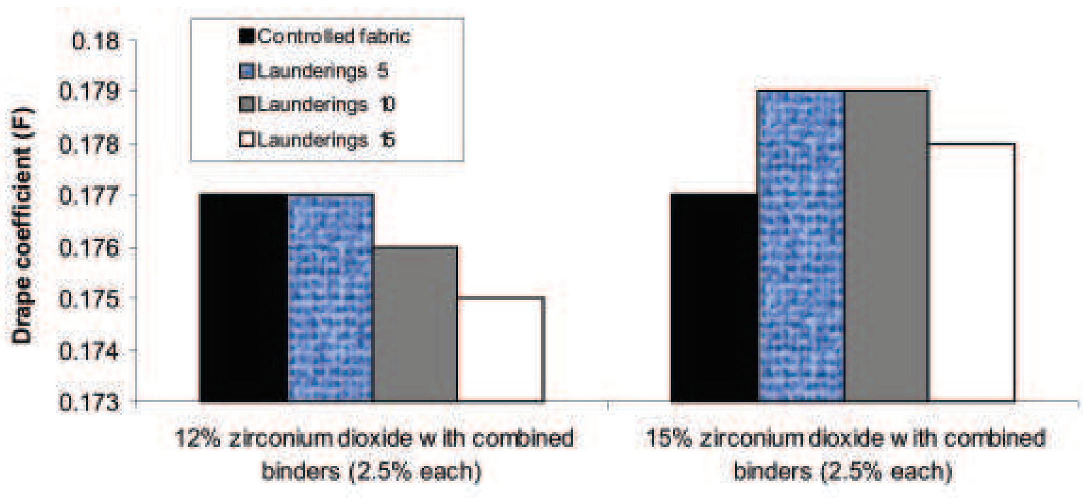

Fig. 4. Drape coefficient of FR finished cotton with combined binders after launderings

of 12 per cent finish concentration with combined binders elongation (warp) was found 7.0 per cent followed by 6.9 per cent after 5,10 and 15 launderings, respectively but further with application of 15 per cent finish concentration elongation decreased as 6.7 per cent after 5,10 and 15 launderings having a critical difference of 0.22. Nair (2002) worked on mercerized cotton to make it flame retardant and chemicals namely phosphorylation, phosphonium chloride, hydroxide, amide, lyophilized pancreatic juice as bio degrading agent and found that by the using of these chemicals fabric stiffness, tensile strength and elongation of the treated fabric were decreased as compared to the controlled fabric.

Elongation of weft wise direction decreased after 5 and 10 launderings as 8.0 per cent consequently after 15 launderings 7.9 per cent after applying the FR finish of 12 per cent concentration with combined binders whereas by the application of 15 per cent finish concentration with combined binders, elongation in weft wise direction was observed 8.1 per cent after 5 and 10 launderings and 7.9 per cent after 15 launderings with CD 0.20.

Drape coefficient in Fig. 4 of controlled fabric was measured 0.177 F that was found same after 5 launderings but after 10 and 15 launderings it was found 0.176 F and 0.175 F respectively by the application of 12 per cent finish concentration with combined binders having significant difference of 3.94 but drape coefficient with 15 per cent concentration of finish and combined binders (2.5% each) was found 0.179 after 5 and 10 launderings and 0.178 after 15 launderings with CD 3.94.

CONCLUSION

After launderings, better results were obtained with 12 per cent FR finish and combined binders (2.5%) regarding all mechanical parameters like bending length, tensile strength, elongation and drape coefficient with increased number of dips (1 dip 1 nip, 2 dip 1 nip and 3 dip 1 nip).

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Economic analysis of *Bt* cotton production in Haryana

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Abstract : The present study was conducted in purposively selected Hisar and Bhiwani districts of Haryana. A random sample of 80 *Bt* cotton growers from 4 randomly selected villages was taken. Per ac cost of production in Hisar district came out to be Rs. 25911 as compared to Rs. 25432 in Bhiwani. Per ac net returns over total cost and net returns over variable cost were higher in Hisar (Rs. 10147 and Rs. 20087) as compared to Bhiwani (Rs. 8139 and Rs. 18674). Per q cost of production in Hisar and Bhiwani was observed as Rs. 3112 and Rs. 3303, respectively as compared to Per q price of Rs. 4250 and Rs. 4230 realized by the respondents of Bhiwani and Hisar districts, respectively.

Key words: Cost of production, economics, *Bt* cotton

Cotton, 'White Gold' or the "King of Fibres", as it is often referred to, is the principal commercial crop of India. Haryana is an important producer of short, medium and superior medium staple cotton. It has recorded about 8 times increase in cotton production with 229.51 per cent increase in area since its inception (1966-67 to 2011-2012). The need for chemical pesticides was reduced by an average of 5-8 sprays/season (Nandal and Punia, 2009). As a consequence of the above comparative advantages of *Bt* over non *Bt*, there has been gradual and consistent replacement of non *Bt* cotton with *Bt* cotton. The present study was, therefore, undertaken to study the comparative economics of *Bt* cotton production in Hisar and Bhiwani districts of Haryana.

Hisar and Bhiwani having 26.29 and 6.49 per cent of total area under cotton and contributing 24.87 and 4.59 per cent, respectively of total cotton production in the state. Therefore, these two districts were selected. Two blocks from these selected districts *i.e.* Agroha from Hisar and Bawani Khera from Bhiwani were selected purposively. From each block, 2 villages namely, Chickenwas and Landhari from Agroha and Baliali and Sui from Bawani Khera were selected randomly. A sample of 20 respondents including small, medium and large farmers from each selected village making a sample of 80 farmers was taken. The survey method consisting of personal interview of selected respondents through specifically designed and pre tested schedule was followed for collecting the required primary data. For studying the costs and returns of *Bt* cotton, the primary data on various items of cost of cultivation such as preparatory tillage, planting and sowing, fertilizer use, irrigation, plant protection, hoeing, picking etc was collected from the selected respondents. These costs were considered as variable costs or working costs. The rental value of land, risk factor and management

Table 1. Category wise number of farmers

District	Small (upto 5 ac)	Medium (6-10 ac)	Large (above 10 ac)	**Total**
Hisar	14	8	18	**40**
Bhiwani	10	21	9	**40**
Total	**24(30.0)**	**29 (36.2)**	**27 (33.8)**	**80 (100)**

Note: Figures in parenthesis percentage to total

Table 2. Cropping pattern of the selected respondents in *kharif,* season (area in ac)

District	Cotton	Guar	Fodder	Other Crops	Fallow	**Total**
Hisar	355	74	42	0	57	**528**
Bhiwani	264	69	38	12	24	**407**
Total	**619 (66.2)**	**143 (15.3)**	**80 (8.6)**	**12 (1.3)**	**81 (8.7)**	**935 (100.0)**

Note: Fig. in parenthesis percentage to total

Table 3. Costs and returns of *Bt* cotton production in Bhiwani and Hisar districts (Per ac)

Items	Bhiwani			Hisar			t-values	Overall	Percentage
	Quantity	Amount (Rs.)	Percentage	Quantity	Amount (Rs.)	Percentage			
1. Preparatory tillage	3	1133	4.5	3	1064	4.1		1099	4.3
2. Pre sowing irrigation	1	383	1.5	1	340	1.3		362	1.4
3. Ridging		98	0.4		97	0.4		98	0.4
4. Seed (g)	900	2067	8.1	900	1900	7.3		1984	7.7
5. Seed treatment	-	-	-	-	-	-		-	-
6. Sowing		317	1.2		280	1.1		298	1.2
7. FYM	-	-	-	-	-	-		-	-
8. Fertilizers (kg)	134	1514	6	147	1514	5.8		1514	5.9
a) Urea	83	472	1.9	90	511	2		492	1.9
b) DAP	48	975	3.8	55	963	3.7		969	3.8
c) Zn	3	67	0.3	2	40	0.2		53	0.2
d) Potash	-	-	-	-	-	-		-	-
9. Fertilizer application		150	0.6		145	0.6		148	0.6
10. Irrigation	3.5	1211	4.8	4	1384	5.3		1298	5.1
11. Hoeing/weeding	3	1075	4.2	3	1000	3.9		1038	4
12. Plant protection	3	1583	6.2	4	1890	7.3		1737	6.8
13. Picking		3833	15.1		4780	18.4		4307	16.8
14. Miscellaneous expenses		533	2.1		530	2		532	2.1
15. Transport expenses		163	0.6		149	0.6		156	0.6
16. Interest		838	3.3		899	3.5		868	3.4
17. Total working cost (1 to 16)		**14898**	**58.6**		**15972**	**61.6**	**8.7***	**15435**	**60.1**
18. Management expenses		1490	5.9		1597	6.2		1543	6
19. Risk factor		1490	5.9		1597	6.2		1543	6
20. Rental value of land		7555	29.7		6745	26		7150	27.9
21. Fixed cost (18 to 20)		**10535**	**41.4**		**9939**	**38.4**		**10237**	**39.9**
22. Total cost (17 + 21)		25432	100		25911	100	1.74*	25672	100
23. Production (q)									
a) Main product (q)	7.7	33172		8.3	35698			34435	
b) Byproduct		400			360			380	
24. Gross returns		**33572**			**36058**		**6.98***	**34815**	
25. Net returns over total cost		**8139**			**10147**		**4.13***	**9143**	
26. Net returns over working cost		**18674**			**20087**		**3.7***	**19380**	
27. Cost of production (Rs./q)		**3303**			**3122**			**3212**	

charges considered as fixed costs were also included for calculating the total cost. The data relate to *kharif,* 2011-2012. Simple budgeting technique was used as analytical tool to analyze the data.

Size of holding and cropping pattern : Data in Table 1 showed that out of total 80 cotton growers selected, 24 were small farmers (30.0%) were medium farmers (36.2 %) and 27 were large farmers (33.8 %). Out of total area of 935 ac cultivated by the respondents of two selected districts in *kharif,* 619 ac (66.2%) was found under cotton cultivation whereas 143 ac (15.3%) was under *guar* (Table 2). The area under fodder and other crops was 92 ac (9.9%). The remaining 8.7 per cent in *kharif* was left out fallow.

Costs and returns of *Bt* cotton production : The costs and returns of *Bt* cotton produced in Bhiwani and Hisar have been compared in Tables 3 to 4. In Bhiwani, the cost of production was Rs. 25432/ac (Table 3). The rental value of land, picking, seed cost, plant protection measures and fertilizer use were the major items of total cost constituting 29.7, 15.1, 8.1, 6.2 and 6.0 per cent, respectively followed by management expenses (5.9%), risk factor (5.9%), irrigation (4.8%), hoeing/weeding (4.2%) and preparatory tillage (4.5%). In case of Hisar, the cost of production/ac was worked out Rs. 25911 (Table 4). The rental value of land, picking, seed cost, plant protection measures, management expenses, risk factor and fertilizer use were again the major items of total cost contributing 26.0, 18.4, 7.3, 7.3, 6.2, 6.2 and 5.8 per cent, respectively followed by irrigation (5.3%), hoeing/weeding (3.9%) and preparatory tillage (4.1%). The comparative analysis of expenditure incurred on different items in two districts shows that/ac expenditure incurred on preparatory tillage, seed, rental value of land and hoeing/ weeding was higher in Bhiwani as compared to that of Hisar (Table 3). But in case of irrigation, plant protection, picking, management expenses and risk factor, the/ac expenditure incurred on these items was higher in Hisar as compared to Bhiwani . The total cost of production/ac for both districts as a whole was worked out at Rs. 25672. The average gross income/ac in Hisar was Rs.36058 as compared to Bhiwani (Rs. 33572). This may be attributed to higher/ac production (8.3q) in Hisar as compared to that (7.7q) Bhiwani. Per ac income for the two districts as a whole was Rs.34815. Per q of *Bt* cotton realized by the growers in Bhiwani and Hisar was reported as Rs. 4360 and Rs. 4344, respectively. Consequently/ac net returns over total cost was higher in Hisar (Rs. 10147) as compared to Bhiwani (Rs. 8139). Similarly, the net returns over variable cost was higher in Hisar (Rs. 20087) as compared to Rs. 18674 in Bhiwani. The net return over total cost and net returns over working cost/ac for the two as a whole was recorded as Rs. 9143 and Rs. 19380, respectively. The cost of production/q in Bhiwani and Hisar was Rs. 3303 and Rs. 3122, respectively. The statistical analysis showed the significant difference between Bhiwani and Hisar districts on total cost/ac by using paired t-test statistics. The statistical analysis also showed the significant difference in net returns, net returns over total cost and net returns over working cost/ ac in Hisar as compare to Bhiwani, respectively.

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An economic evaluation of *Bt* cotton cultivation in Punjab

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ABSTRACT : The study has been conducted in Punjab based on farm level experience collected from 120 farmers(60 *Bt* and 60 non *Bt* cotton growers) spreading over three districts *viz.*, Ferozepur, Muktsar and Bathinda during 2007-2008. The study brought out that *Bt* cotton yielded around 24 – 28 per cent higher than non *Bt*. The return over variable cost in *Bt* and non *Bt* cotton was Rs. 25428 and Rs. 19971/ha, respectively. *Bt* cotton fetched Rs.4486/ha (23.44%) higher returns than non *Bt*. The regression analysis brought out that the coefficient for seed, human labour, fertilizer and irrigation turned out to be positively significant in *Bt*, while regression coefficient for plant protection chemicals and human labour came out to be positively significant in the case of non *Bt* cotton.

Key words: *Bt* cotton, cotton cultivation, performance evaluation

Cotton, the "White Gold" enjoys a predominant position amongst all the cash crops. Despite having the largest area under cotton in the world, India ranks third in the world output of cotton due to its abysmally low average yield of 300-400 kg against the world average of 580/ha. Out of the total pesticides used in country as much as 54 per cent are used for control of pests in cotton alone, out of which nearly 60 per cent are used for the control of bollworms (Singh and Kaushik, 2007). The adoption of transgenic crops like *Bt* cotton helped in protecting the crop against the potentially most damaging pest and reduced the risk of crop failure. Three *Bt* cotton hybrids namely, MRC 12 *Bt*, MECH 162 *Bt* and MECH 184 *Bt* were released for commercial cultivation in south and central states in 2002.

Punjab is the fourth largest cotton producing state in India and the major cotton producing districts, *viz.*, Ferozepur, Bathinda, Muktsar and Mansa produce 92 per cent of the total cotton production in the state and due to the attack of American bollworm it started declining. This further caused adverse effect on the cotton industry and farmers went under huge debt. This was also one of the reported reasons that many farmers commit suicide in south west Punjab. The adoption of *Bt* cotton could help in protecting the crop against the potentially most damaging pest and thus could reduce the risk of crop failure.

Due to high concentration of the cotton crop in south west Punjab, it is commonly called as the "cotton belt of Punjab". This call for the need to study the economics of *Bt* cotton as the entire region depends on it for its livelihood. In order to study the entire scenario of cotton, this research problem was undertaken with the following objectives *i.e.* to study the comparative economics of *Bt* cotton and non *Bt* cotton in Punjab and to study the productivity determinants of *Bt* cotton as well as non *Bt* varieties.

The study was conducted in south western Punjab popularly known as "cotton belt". This region comprises of Ferozepur, Faridkot, Sangrur, Patiala, Muktsar, Mansa and Bathinda districts. Multistage sampling design with districts as the first stage sampling unit, block as the second stage, and village as third stage and respondents as the fourth and final stage sampling unit was adopted for the purpose of the study. Ferozepur, Muktsar and Bathinda districts were selected for the investigation. A list of all the blocks falling under the selected districts was prepared. Two blocks from each district were chosen randomly. Thus Abohar and Fazilka from Ferozepur district, Muktsar and Malout from Muktsar district and Bathinda and Talwandi Sabo from Bathinda district were selected randomly. From each selected block, two clusters of 2-4 villages were selected at random. Using random sampling technique, 60 *Bt* cotton growers and 60 non *Bt* cotton growers were selected for intensive survey. The *Bt* cotton farmers were those who only cultivated *Bt* cotton and not any other hybrid cotton. Total sample of 120 farmers covering six blocks and three districts of Punjab were finally chosen for the ultimate analysis.

In order to study the yield response of

cotton, Cobb-Douglas production function and linear production function were tried with different combinations of independent and dependent variables. Finally, Cobb-Douglas production function of following type was found to be better fit in terms of the value of coefficient of determination, level of significance of regression coefficient and logical signs of regression coefficients.

$$Y = a_0 \prod_{i=1}^{n} X_i^{bi} e^u$$

Where, Y represents the value of productivity per hectare of cotton crop. X_i, the selected explanatory variables (per ha); a_0 the technical efficiency parameter and b_i the coefficient of production elasticity of the respective variable x_i at the mean level of input used and output obtained. The 'e' is an error term. The estimated form of the equation becomes:

$$\text{Log } Y = \log a_0 + \sum_{i=1}^{n} b_i \log X_i + u$$

$$\text{Log } Y = \log a_0 + b_1 \log X_1 + b_2 \log X_2 + \ldots b_n \log x_n + u$$

Details of variables:-

The details of the variable along with the units used in the analysis are under:-

- Y = Value productivity of cotton (Rs/ha)
- X_1 = Seed (Rs/ha)
- X_2 = Fertilizers (N, P, K, Zn) (Rs/ha)
- X_3 = Plant protection chemicals (Rs/ha)
- X_4 = Irrigation (Number)
- X_5 = Human labour (Rs/ha)
- X_6 = Machine labour (Rs/ha)

Physical input use pattern : The variety wise input use pattern for cotton is depicted in Table 1. The pesticide spraying was noticed to be 40.67 per cent less in *Bt* cotton against non *Bt.* The overall seed rate was found to be 2.27 kg/ha and 16.2 kg/ha in case of *Bt* and non *Bt* cotton, respectively. The nitrogenous fertilizer used in *Bt* was 233.62 kg/ha where as in non *Bt* it was 212.01 kg/ha. DAP used in *Bt* cotton was 103 kg/ha and in the case of non *Bt* it was 90.57 kg/ha. Similarly, the use of zinc sulphate and potassium was also higher in case of *Bt* cotton. The irrigations applied was calculated as 5.78 for *Bt* cotton and 3.77 for non *Bt* cotton. The numbers of irrigations in case of *Bt* cotton were 53.32 per cent more than that of non *Bt* cotton.

Variable cost of *Bt* and non *Bt* cotton : The various variable cost components have been estimated for *Bt* cotton as well as non *Bt* cotton and the same have been depicted in Table 2. Farmers spent Rs. 3363/ha on seeds of *Bt* cotton which accounted for 14.24 per cent of the total variable cost as against only Rs. 555/ha accounting for merely 2.90 per cent of the total variable cost in non *Bt* cotton non *Bt* cotton. Farmers spent Rs. 4148/ha (17.56% of total variable cost) on plant protection chemicals on *Bt* cotton in the state. On the whole, farmers spent Rs. 6220/ha in the state on plant protection chemicals which constitutes 32.50 per cent of the total variable cost. In case of *Bt* cotton the expenditure on plant protection chemical was found to be Rs. 2072/ha less than that of non *Bt* cotton. This cost was 33.31 per cent less in *Bt* cotton than that of non *Bt*. The total cost of all these four fertilizers/nutrients, Urea, DAP, potash and zinc was Rs. 2261 (9.57%)/ha of total variable cost as against Rs. 2003 (10.47%) in case of non *Bt*. Hence, the expenditure on fertilizers was Rs 258 (12.88%)/ha more than that of non *Bt*. The machine power was mainly used for tillage operations, irrigation; inter culture, spraying and for transportation purposes. On an average, farmer spent Rs. 2183/ha on irrigation which was the highest proportion of variable cost on this head, constituting 9.24 per cent. The second highest proportion of variable cost on account of diesel was incurred on tillage operations. The cost incurred on transportation activities such as transportation of farm yard manure and transportation of produce to market were estimated to be Rs. 360/ha which constituted 1.52 per cent of the total variable cost. In case of non *Bt* the machine power was mainly used for tillage operations, irrigation, inter culture, spraying and transportation purposes. The highest proportion of variable cost of diesel head was incurred on tillage operations in the form of diesel consumption. The farmers in the state spent Rs. 1655/ha on tillage operations which constituted 8.65 per cent of the total variable cost. Hence, in *Bt* cotton the expenditure on machinery in the form of diesel consumption was Rs 1504/

Table 1. Physical input use pattern for *Bt* and non *Bt* cotton cultivation, Punjab.

Inputs	Ferozepur		Muktsar		Bathinda		Overall`		Per cent difference
	Bt	Non *Bt*	*Bt*	Non *Bt*	*Bt*	Non *Bt*	*Bt*	Non *Bt*	
Sprayings/ha	8	14	7	10	6	12	7	12	- 40.67
Fertilizer urea (kg/ha)	243.91	188.34	225.39	209.95	231.56	237.74	233.62	212.01	10.19
DAP	104.98	83.36	106.83	83.36	98.8	104.98	103.54	90.57	14.32
Potassium	3.09	3.09	12.35	8.03	11.73	6.18	9.06	5.77	57.02
Zinc (kg/ha)	4.32	3.71	4.32	2.41	7.41	6.18	5.35	4.1	30.49
Seed (kg/ha)	2.32	15.07	2.17	17.54	2.32	15.99	2.27	16.2	- 85.99
Irrigations/ha	6.3	3.65	5.1	3.85	5.95	3.8	5.78	3.77	53.32

ha more than that of non *Bt*. This cost was 40.80 per cent more in *Bt* than that of non *Bt*. This difference in variable cost was due to the excessive numbers of irrigation and inter culture activities performed in case of *Bt* cotton.

The labour expenditure mainly incurred on tillage, irrigation, hoeing, spraying, picking, loading, unloading activities, etc. The total labour cost was calculated as Rs. 8667/ha which constituted 36.69 per cent of the total variable cost in *Bt* cotton in comparison to Rs.6680/ha which constituted 34.38 per cent of the total variable costs in case of non *Bt*. Hence, the labour operations were more in case of *Bt* cotton. This led to increase the cost by Rs 1987/hain case of *Bt* cotton than that of non *Bt*. Hence, in case of *Bt* cotton the variable costs were Rs 4486/ha more than that of costs incurred in non *Bt* due to more expenditure on seeds, irrigation, hoeing and picking.

Economic advantage of *Bt* cotton over non *Bt* cotton : The comparative analysis of returns from *Bt* cotton and non *Bt* cotton has been presented in Table 3. Total variable costs were found to be Rs. 23622/ha in case of *Bt* cotton and 19136 in case of non *Bt* with difference of Rs. 4486 *i.e.* 23.44 per cent high in *Bt* as compared to non *Bt*. The average yield of *Bt* and non *Bt* was found to be 21.18 q/ha and 16.62 q/ha. This shows that with higher cost of cultivation, *Bt* also give higher yield per hectare. The yield of *Bt* cotton was higher by 20 to 50 per cent than non *Bt* cotton. The average difference in yield of *Bt* and non *Bt* cotton was 4.56 q/ha (27.44%). The average price received by the farmer for *Bt* was Rs. 2311 per quintal. In case of non *Bt* the average price received was Rs. 2353/q. The average overall return from in *Bt* was calculated as Rs. 48947/ ha in comparison with Rs. 39107/ha in case of non *Bt*. Even at higher cost of cultivation of *Bt* Rs 23622 (Rs 19136 in non *Bt*), *Bt* gives higher returns over variable costs. The returns over variable costs were Rs 25428 from *Bt* as compared to Rs 19971 from non *Bt*. This showed that the cultivation of *Bt* was much more profitable than non *Bt*.

Determinant of the yield were studied with the help of Cobb Douglas form of regression model and the same has been presented in Table 4. In case of *Bt* cotton, coefficient of multiple determination (R^2) came out to be 0.695 indicating that 69.5 per cent of the variation in the dependent variable were explained by explanatory variables. So far the identification of the variables having significant effect was concerned, it was seen that regression coefficient for fertilizer and irrigation turned out to be positively significant, though at 10 per cent level of significance, implying with one per cent increase in expenditure on fertilizer and irrigation, the value productivity of *Bt* cotton would increase by 0.2 and 0.185 per cent respectively .The regression coefficient for seed came out to be significant at 5 per cent probability level. If one per cent expenditure is increased on seed, the value productivity of *Bt* cotton would increase by 0.407 per cent. Regression coefficient for human labour came out to be positively significant at one per cent level of significance. If one per cent expenditure is increased in human labour, the value productivity of *Bt* cotton would increased by 0.198 per cent. The regression coefficient for plant protection chemicals and machine labour came out to be non significant.

In case of non *Bt* cotton, coefficient of multiple determinations (R^2) came out to be 0.488 indicating that 48.8 per cent of the variation in the dependent variable was explained by explanatory variables. So far the identification of

Table 2. Variable costs in cultivation of *Bt* and non *Bt* cotton in Punjab. (Rs/ha)

Items		*Bt* cotton				Non *Bt* cotton				Difference b/w
		Ferozepur	Muktsar	Bathinda	Overall	Ferozepur	Muktsar	Bathinda	Overall	*Bt* and non *Bt*
Seed		3402(14.60)	3501(14.57)	3186(13.55)	3363(14.24)	542(2.90)	677(3.77)	445(2.14)	555(2.90)	2808(505.95)
Spraying chemicals		4495(19.29)	4211(17.52)	3736(15.88)	4148(17.56)	6786(36.29)	5482(30.56)	6391(30.77)	6220(32.50)	- 2072(- 33.31)
Fertilizers	Urea	1184(5.08)	1086(4.52)	1110(4.27)	1127(4.77)	950(5.08)	1008(5.62)	1142(5.50)	1033(5.40)	94(9.10)
	DAP	997(4.28)	1002(4.17)	936(3.98)	978(4.14)	858(4.59)	785(4.38)	997(4.80)	880(4.60)	98(11.14)
	Potash	25(0.11)	103(0.43)	93(0.40)	73(0.31)	25(0.13)	64(0.36)	49(0.24)	46(0.24)	27(58.70)
Zinc		66(0.28)	66(0.27)	116(0.49)	83(0.35)	54(0.29)	40(0.22)	38(0.18)	44(0.23)	39(88.64)
Sub total		**2272(9.75)**	**2256(9.39)**	**2255(9.59)**	**2261(9.57)**	**1887(10.09)**	**1897(10.58)**	**2226(10.72)**	**2003(10.47)**	**258(12.88)**
Diesel used	Tillage operation	1810(7.76)	1658(6.90)	1572(6.68)	1680(7.11)	1975(10.56)	1552(8.65)	1438(6.92)	1655(8.65)	25(1.51)
by machine	Irrigations	1447(6.21)	2075(8.63)	3026(12.86)	2183(9.24)	599(3.20)	1120(6.24)	1713(8.25)	1144(5.98)	1039(90.82)
	Interculture	657(2.82)	661(2.75)	1115(4.74)	811(3.43)	683(3.65)	448(2.50)	670(3.23)	600(3.14)	211(35.17)
	Spraying	300(1.29)	68(0.28)	78(0.33)	149(0.63)	-(-)	83(0.46)	46(0.22)	43(0.22)	106(246.51)
	Transportation	293(1.26)	442(1.84)	346(1.47)	360(1.52)	118(0.63)	303(1.69)	285(1.37)	235(1.23)	125(53.19)
Sub total		**4507(19.34)**	**4904(20.40)**	**6137(26.09)**	**5182(21.94)**	**3375(18.05)**	**3506(19.55)**	**4152(19.99)**	**3678(19.22)**	**1504(40.89)**
Hired	Tillage Operation	91(0.39)	97(0.40)	70(0.30)	86(0.36)	39(0.21)	19(0.11)	38(0.18)	32(0.17)	54(168.75)
Labour	Irrigations	369(1.58)	249(1.03)	156(0.66)	258(1.09)	107(0.57)	71(0.40)	99(0.48)	92(0.48)	166(180.43)
	Hoeing/ Interculture	3050(13.09)	3166(13.17)	2791(11.87)	3003(12.71)	2155(11.52)	2666(14.86)	2919(14.06)	2580(13.48)	423(16.40)
	Spraying	234(1.00)	427(1.78)	144(0.61)	268(1.14)	526(2.81)	338(1.89)	623(3.00)	496(2.59)	- 228(- 45.97)
	Removing Sticks	130(0.56)	337(1.40)	125(0.53)	197(0.83)	-(-)	222(1.24)	93(0.45)	105(0.55)	92(87.62)
	Fertilizer Application	114(0.49)	273(1.14)	112(0.48)	166(0.70)	57(0.30)	84(0.47)	95(0.46)	79(0.41)	87(110.13)
	Picking & Loading	4645(19.93)	4613(19.19)	4808(20.44)	4689(19.85)	3226(17.25)	2974(16.58)	3688(17.76)	3296(17.23)	1393(42.26)
Sub total		**8633(37.03)**	**9161(38.12)**	**8206(34.89)**	**8667(36.69)**	**6110(32.67)**	**6375(35.54)**	**7555(36.38)**	**6680(34.91)**	**1987(29.75)**
Total variable cost		**23310(100)**	**24033(100)**	**23520(100)**	**23622(100)**	**18700(100)**	**17937(100)**	**20770(100)**	**19136(100)**	**4486(23.44)**

Figures in the parentheses indicate percentages

Table 3. Economic advantage of *Bt* cotton over non *Bt* cotton, Punjab

Items	Ferozepur			Muktsar			Bathinda			Overall		
	Bt	Non *Bt*	Difference	*Bt*	Non *Bt*	Difference	*Bt*	Non *Bt*	Difference	*Bt*	Non *Bt*	Difference
Yield (q/ha)	21.19	18.55	2.64(14.23)	22.98	15.2	7.78(51.18)	19.36	16.11	3.25(20.17)	21.18	16.62	4.56(27.44)
Market price (Rs/q)	2268	2400	-132(-5.50)	2418	2408	10(0.42)	2249	2251	-2(-0.09)	2311	2353	-42(-1.78)
Cost of cultivation (Rs/ha)	23310	18700	4610(24.65)	24033	17937	6096(33.99)	23520	20770	2750(13.24)	23622	19136	4486(23.44)
Return from main product (Rs/ha)	48059	44520	3539(7.95)	55566	36602	18964(51.81)	43541	36264	7277(20.07)	48947	39107	9840(25.16)
Return from byproduct (Rs/ha)	-	-	-	310	-	310	-	-	0	103	-	103
Gross returns (Rs/ha)	**48059**	**44520**	**3539(7.95)**	**55876**	**36602**	**19274(52.66)**	**43541**	**36264**	**7277(20.07)**	**49050**	**39107**	**9943(25.43)**
ROVC (Rs/ha)	24749	25820	-1071(-4.15)	31843	18665	13178(70.60)	20021	15494	4527(29.22)	25428	19971	5457(27.33)

Figures in the parentheses indicate percentages

Productivity determinants of *Bt* Cotton and Non *Bt* Cotton

Table 4. Determinants of yield on *Bt* cotton and non *Bt* cotton cultivation for sample respondents, Punjab, 2007-08: Results of SPSS

Variable	Symbol	Unit	Regression coefficient	
			Bt cotton	Non *Bt* cotton
Intercept	a$_0$		1.617**(0.572)	1.033$(0.599)
Seed	X_1	Rs. /ha	0.407*(0.0.175)	0.149$(0.078)
Fertilizer	X_2	Rs. /ha	0.200$(0.104)	0.09984ns(0.110)
Plant protection chemicals	X_3	Rs. /ha	-0.04357(0.062)	0.229**(0.060)
Irrigation	X_4	Number	0.185$(0.095)	0.09866ns(0.169)
Human labour	X_5	Rs. /ha	0.198**(0.067)	0.450**(0.110)
Machine labour	X_6	Rs. /ha	-0.0329ns(0.037)	0.04089ns(0.077)
R^2 F ratio			0.695(0.03893)	0.488(0.08197)
Observations			60	60

Figures in the parentheses show the respective standard error of the coefficient.
**, * and$ show the significance at 1%, 5% and 10% levels, respectively

the variables having significant effect is concerned it was seen that regression coefficient for seed came out to be significant at ten per cent level of significance. If one per cent expenditure is increased on seed, the value productivity of *Bt* cotton would increase by 0.149 percent. The regression coefficient for plant protection chemicals and human labour came out to be positively significant at one per cent level of significance. If one per cent expenditure is increased in plant protection chemicals and human labour, the value productivity of *Bt* cotton would increase by 0.229 and 0.450 per cent respectively. The regression coefficient for fertilizer, irrigation and machine labour came out to be non significant.

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